Experimental Wireless

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Experimental Topics.

Price Cutting in Wireless Goods.

The business of selling wireless goods has developed at such an enormous pace during the last year or so, that it is not surprising to find it marked by certain abnormal and, in some cases, undesirable features. All sorts and conditions of people have jumped into the New Eldorado of wireless trading, determined to exploit the enthusiasm of the public for the benefit of their own pockets. It is no uncommon thing to see wireless goods exposed for sale in the shops of stationers, hairdressers, pawnbrokers, second-hand furniture dealers, and many other traders whose normal business does not call for the slightest scientific or technical qualification. It may be that here and there among these folk is one who as a very keen enthusiast has studied wireless to some good purpose, and is competent to judge the quality of the apparatus he is selling and to advise purchasers honestly and well. But we fear that the majority of such traders, however, well-intentioned they may otherwise be, fall sadly short in the technical knowledge which is necessary to sell wireless goods with advantage to the customer as well as profit to themselves. Misrepresentation of goods, or the sale of unsuitable goods, whether unintentional or not, cannot but lead to disappointment of the public, and to injury to the wireless industry as a whole. This is only one of the difficulties from which the wireless industry is suffering; a far more serious matter is the epidemic of price-cutting which has recently set in. It is a matter of common knowledge that there are firms who have no regard for the prices of standard goods fixed by manufacturers, but "cut" these prices without compunction in order to attract the bargain hunter. We say unhesitatingly that this is a practice which is contrary to all fair-trading principles, and we ask our readers not to lend it their support. It should be clearly understood that we are not arguing against fair competition, however keen it may be. We are not advocating the maintenance of high prices, nor are we expressing any approval of "profiteering." On the contrary, any fair competition amongst manufacturers or retailers which results in more favourable prices for the consumer without sacrifice in quality is to be whole-heartedly commended. But we contend that any manufacturer is entitled to fix the prices at which his goods shall be sold to the public. He takes the risk of his price being acceptable to the public, and he takes the risk of a rival manufacturer offering an equally suitable or a better article at a lower price. If he finds his competitors are beating him out of the market he must improve his manufacturing methods, or be content with a lower margin of profit, and meet the competitive prices. That is fair competition and is all to the good from the consumer's point of view. Whatever price, however, the manufacturer

does place on his goods, he is entitled to have respected by his agents, and by the retail trade in general. Price-cutting of the kind indicated is very disturbing and very unfair in various ways. The manufacturer may find in a paper alongside his own advertisement, another advertisement from a price-cutting firm, of his own goods offered at considerably reduced prices. One of his own retail agents may find his stock almost unsaleable, because a shop round the corner is offering the same goods at "cut" prices. The obvious remedy of refusing supplies to the price-cutting firms is only a partial remedy; by various devious methods they manage at present to secure a sufficient stock of goods of standard make to enable them to shout about their "cheap" prices. No doubt in time all sources of supply will be closed to them, as has been successfully done in other trades where similar price-cutting tactics were adopted, and then the industry will be freed from what is a growing and an objectionable practice. The reputable manufacturer who believes in the maintenance of a fair price for his goods, backs his price with the guarantee of good quality and good service. A customer buying standard goods direct from the maker, or through an accredited agent, knows that he will get a perfect article, or, if not, that any defective article will be replaced or made good. There is fair service behind a fair price. There is no such service behind a "cut" price; the manufacturer does not stand behind the price-cutter as he does behind his accredited agent, and this fact alone should make wireless experimenters cautious in their purchases. The experimenter cannot afford to have his work go wrong because of defective apparatus or material; it wastes valuable time as well as money, and a "cut-price" purchase may well prove to be anything but a bargain in the long run.

Amalgamation.

After many months of negotiations and renewed negotiations peace seems to reign in the amateur transmission world. At the last meeting of the Radio Transmitters' Society the motion that the Radio Transmitters' Society should amalgamate with the Transmitter and Relay Section of the Radio Society of Great Britain was carried by a substantial majority. The meeting, however, was not uneventful, as several speakers seemed strongly opposed to co-operation, but while, perhaps, their arguments were quite logical, we think that co-operation is the only satisfactory solution to the problem. Not only should the combined forces of the two societies give greater strength to the amateur position, but the amalgamation should prove mutually beneficial. We wish the new body every success, and trust that they will do much to further the amateur movement.

Concerning Calibration.

The scores of variable condensers, wavemeters and other instruments which have passed through the calibration department of the EXPERIMENTAL WIRELESS Laboratory during the last few months have provided much food for thought. We begin to wonder if the meaning of calibration is really fully appreciated by the radio enthusiast. Perhaps a few words of advice to those who are contemplating forwarding apparatus may be of value, as many instruments which have found their way to the laboratory have been immediately returned for mechanical alterations before calibration has been possible. Variable condensers, perhaps, are the worst offenders. It is quite common to receive a condenser which shorts over some 50 or 60 degrees of the scale, while condensers without a zero mark have been very prolific. Another common fault is backlash in the dial. This, of course, results in a curve more resembling a damped wave train than a straight line. Wavemeters are also a very fruitful source of trouble. Those who are about to construct a wavemeter would be well advised to use as large a variable condenser as possible in conjunction with the minimum number of inductances. There is a lighter side to the calibration department, however, as amongst other things which have been received were a thermo-ammeter described as a "milliammeter believed to be too fast," and a heap of powdered glass to be calibrated as a hydrometer. Readers who utilise the calibration service would not only benefit themselves, but assist us materially if they would make sure that their apparatus is in suitable condition and worthy of calibration before despatch.

Directive Radio Telegraphy and Telephony.

By R. L. SMITH-ROSE, Ph.D., M.Sc., D.I.C., A.M.I.E.E.

III.—THE CONSTRUCTION AND USE OF A PORTABLE DIRECTION FINDER.

(*Continued from page 257.*)

During the last few years there has been considerable development in directional work, and there are obviously many applications of directional transmission and reception. We give below a general summary of modern methods and practice.

THE simple form of frame coil is now well known among experimenters as an alternative to the open aerial for reception purposes. It is seldom, however, that the directive properties of the coil are utilised, except possibly to eliminate or reduce interference. With a direction-finding receiver, however, many interesting experiments may be carried out, which will be very instructive both on the practical and theoretical sides of radio communication and the general principles of the propagation of electro-magnetic waves. Some precautions have to be adopted in the design, construction, and operation of a set in order that accurate readings of direction may be obtained. In the present article it is proposed to describe, in sufficient detail to enable construction to be carried out, a direction finder of the single-frame type, which combines accuracy of observation and ease of operation with complete portability of the whole instrument.

(a) Dimensions of Coil Frame and Stand.

In order that observations may be carried out at appreciable ranges of transmission, it is essential that stations of moderately high output power be used, which necessitates working on wave-lengths certainly not lower than 1,000 metres. Besides obtaining the advantage of the existence of stations of superior power on these longer waves, there is added that of longer and more regular transmissions. On the shorter waves, such as 600 metres, ordinary reception indicates that the transmissions of any given ship or shore station are very erratic in their frequency, and also usually of comparatively short duration—less than one minute—making reliable D.F. observations extremely difficult. The set about to be described is, therefore, given the convenient range of wave-lengths of from 1,000 to 10,000 metres, although it is a comparatively simple matter to extend this range in either direction.

The general appearance of the D.F. set is seen from the drawing in Fig. 1 and the photographs Figs. 2 and 3.

To cover the above range of wave-lengths two frame coils are used, each capable of being mounted on a rotating platform. For the larger coil a skeleton wooden frame is constructed of size 4 ft. square by 8 ins. deep. It is very simply made of 1″ square rods with brace pieces at the corners to give rigidity, as shown in Fig. 4. The 1″ square wooden strips forming the corners should be of hard teak and well-soaked in paraffin wax to provide adequate insulation for the winding, which is spaced by slots in the wood at $\frac{1}{8}$″ apart. Alternatively combs of ebonite or micanite may be provided, if desired. The frame is then wound with 34 turns of No. 20 S.W.G. silk-covered copper wire. Bare wire may be used for the coil, but is not recommended on account of the possibility of contact between adjacent turns should the wire become slack after it is wound. The "area-turns" of this coil equal 544 square-foot-turns, and its effective inductance is about 3 millihenries.

The smaller coil is of similar construction, but 2 ft. 6 ins. square, and wound with 25 turns at $\frac{1}{8}$″ spacing. The "area-turns" of the coil equal 156 square foot-turns, and the effective inductance is nearly 1.2 millihenries.

The tuning condensers for the set are mounted on an ebonite panel, which fits on the lower side of either coil frame. The panel

contains one variable air condenser of maximum capacity 0·0011 microfarad, with fixed mica condensers of capacity 0·001, 0·002, 0·004, and 0·008 microfarad. Switches are provided for connecting the fixed units in parallel with the variable condenser, so as to obtain a continuous variation of capacity up to 0·016 microfarad. This range is amply sufficient to tune the small coil over the wave-lengths from one to six kilometres, and the large coil from two to ten kilometres.

The wooden platform upon which the coils are mounted by simple bolts and wing nuts is carried upon a hollow brass spindle which passes through the top of a large wooden box, being supported on a steel pivot at the bottom of the box, as shown in the sectional drawing in Fig. 5.

The box indicated is constructed of ½" wood, and is of external dimensions 23" by 18" by 15" high, although the actual size may need to be varied to suit the amplifier and batteries in use. As shown in Figs. 1

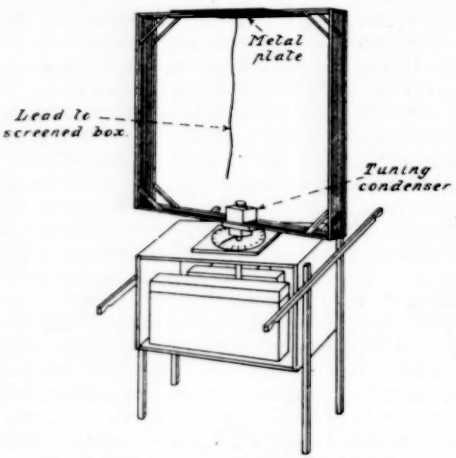


Fig. 1—General arrangement of the direction finder.

and 5, the box is mounted on legs, with its lower side about 14" above the ground, and it is also provided with a pair of carrying handles (see photograph Fig. 3). The outside of the box is entirely covered with tinned iron sheet of about 30 mils. thickness, and the open side of the box is provided with a tinned-iron lid, which is a good tight fit over the box, and provides an overlap of at least two inches. This lid is provided with handles to enable it to be removed, and also two circular holes through which the amplifier controls may be manipulated. The box serves as a shielded container for the amplifier, its associated batteries, and all connecting leads.

If the set is to be used much for outdoor work, it is recommended that the metal shield be protected with paint or enamel. Care should be taken, however, not to cover the portions of either the box or lid where these overlap, for good conductivity is required across this overlap joint, and the metal should be kept clean and bright.

(b) Apparatus and Circuit Arrangements.

The actual type of amplifier employed in the set is immaterial so long as it gives good reception for all wave-lengths from 1·0 to 10·0 km. The point to be borne in mind is that direction observations are made on a minimum or zero signal, and it is the rate of change of the signal strength near the minimum that determines the accuracy of the observation.

To give an adequate receiving range on the frame coil it is preferable to have at least three stages of radio frequency amplification. Following the detecting valve, there should be a choice of one or two stages of audio-frequency amplification. These will be found to considerably improve the accuracy to which the bearings can be observed, although the amplification should not be strained to the point of introducing valve noises.

Three low-frequency stages may be employed in favourable circumstances, but it is seldom that this arrangement can be maintained quiet while giving efficient amplification, and it is only by preserving a background of absolute silence that accuracy of bearings can be obtained.

If still greater sensitivity is desired more radio-frequency stages may be added, but it will be necessary to have an easily adjustable control to maintain the series stable. A potentiometer across the filament battery, by means of which the grids of all the high-frequency valves may be given a positive potential forms a convenient control. With such an arrangement it is usually prohibitive to employ any intential reaction ; for if good bearings are to be obtained self-oscillation of the set must be entirely avoided. With careful design and construction, six high-

frequency valves, followed by a detector and two low-frequency valves, may be handled successfully, but this represents about the upper limit of amplification for D.F. purposes.

For such a number of valves the filament battery should be of adequate capacity, but since the set is to be portable, the size and weight of the battery must be considered. In the set illustrated ordinary "R" type valves were employed with a 6-volt 50-ampere-hour accumulator battery, but this could, of course, be reduced if dull-emitter valves are employed. The high-tension battery is a compact unit, preferably built up of small separate dry cells. The general arrangement of the amplifier and batteries inside the box is shown in the drawings in Figs. 1 and 5. These are all carefully insulated on paraffin blocks or porcelain legs from both the box and the brass spindle, supporting the coil. The batteries are placed behind the amplifier, and the latter is arranged so that its control handles may be manipulated through the hole in the metal cover closing the front of the box.

In wiring up the set, the ends of the D.F. coil are arranged to be at the centre of the lower side, where they are connected directly to the terminals of the condenser panel (Fig. 6). From the condenser terminals, the leads pass down the hollow spindle into the apparatus box, where they are brought out through a hole in the side of the spindle to the amplifier terminals. A sufficient length of the flexible leads should be allowed at this point to permit of the rotation of the frame for at least one turn in either direction. If it is desired to improve the selectivity of the whole receiver a loose-coupling arrangement may be employed, using honeycomb coils and a two-coil plug-in holder mounted inside the screened box. The leads passing down the spindle would then be connected to one coil, forming a primary coupling coil in parallel with the main frame and tuned by a parallel variable condenser. The secondary coil is connected to a variable condenser, also mounted inside the box, and the amplifier then connected across this secondary condenser.

Although the spindle actually makes metallic contact through the pivot with the screen cover of the box, it is advisable to make a more reliable connection by means of a flexible lead soldered to both spindle and box.

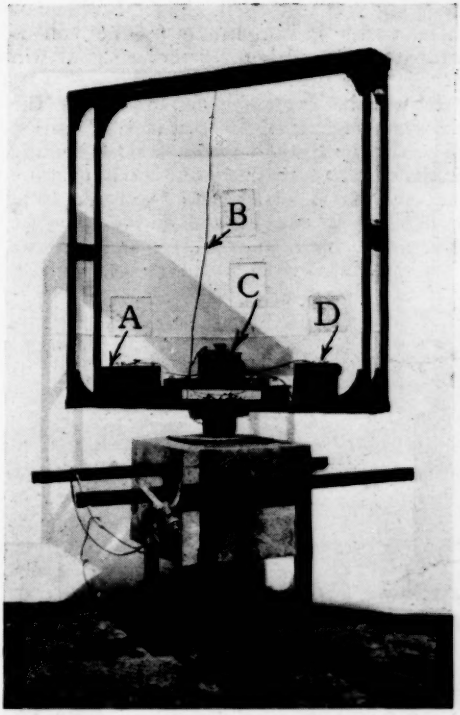


Fig. 2—View of portable direction finder showing A, oscillator; B, lead from capacity plate to box; C, tuning condenser panel; D, oscillator battery.

A brass pointer is also sweated or clamped on to the spindle of suitable dimensions to rotate over a graduated cardboard scale one foot in diameter mounted on wood on the top side of the box (see Fig. 5). This scale should be accurately graduated from 0° to 360°.

For the taking of bearings upon C.W. stations it is necessary to employ a suitable form of local oscillation generator. Special precautions are, however, necessary in the use of this, for if any stray field from the oscillator links the D.F. coil, the resulting induced e.m.f. in the coil will vary as the coil is rotated, and at some point will pass through zero, or at least a minimum. Now the signal heard in the telephones is the beat note produced by interference between the

incoming and local oscillations. If either of these varies in amplitude as the coil is rotated the resulting telephone signal will vary in intensity.

It will be evident, therefore, that the observed reading on the coil in the position of minimum signal may be a false bearing produced by the variation in the linkage by the coil of the stray field from the local oscillator. It is often found, for example, that a set operated in this manner shows four minima in a rotation of the coil through 360°, two of these being genuine minima of bearing and the other two being false minima due to the oscillator.

The most satisfactory method of avoiding this trouble is to screen the oscillator in such a thorough manner that the stray field acting on the D.F. coil is reduced to a negligible quantity. Very elaborate precautions are necessary to attain this end, as will be described in a later article. A simpler alternative, which may be employed in many elementary experiments in direction finding, is to mount the oscillator, with its associated batteries, within the frame coil in the manner shown in the photograph in Fig. 2. By this means the coupling between the oscillator and the receiving frame is fixed, and any variation in the local oscillating e.m.f. is thus avoided. The chief disadvantage of this arrangement is that the strength of the local induced oscillation is not under control, and it is difficult to run the average type of valve oscillator at a low enough output to permit of the optimum signal strength being obtained on the receiver.

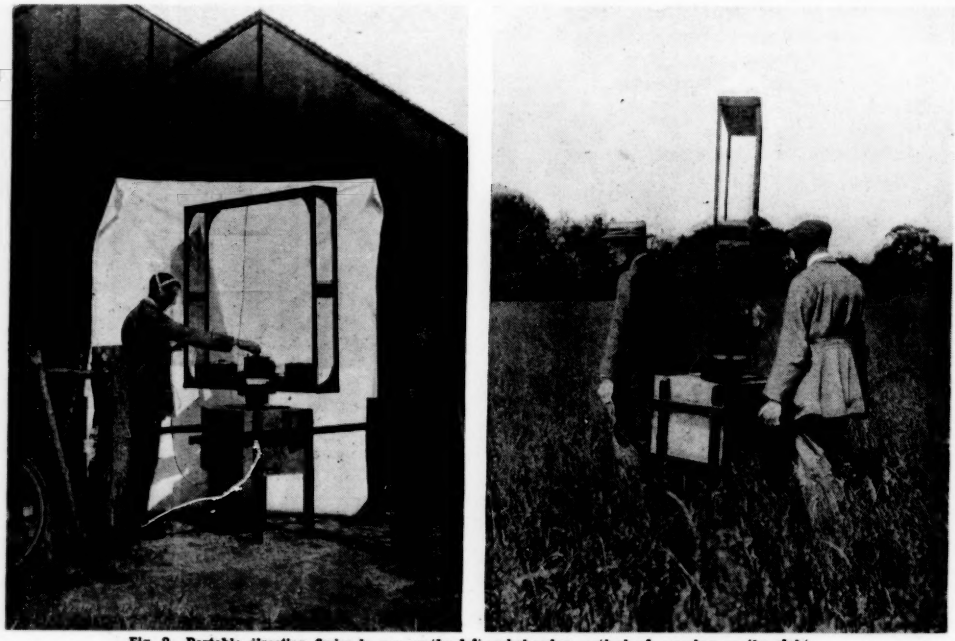


Fig. 3—Portable direction finder in use on the left and showing method of carrying on the right.

(c) Setting up and Operation of the Direction Finder.

In setting-up the receiver for the taking of bearings the set should be stood on a level surface so that the axis of rotation of the coil is as nearly vertical as possible. It is usually most convenient to have the coil set so that the pointer reads directly on the scale in degrees from the true geographical North, and for this orientation of the coil a good type

of prismatic compass is required. The coil is first turned so that the pointer indicates 90° on the scale, and then, standing at a distance of ten or twelve feet from the set, a sight is taken with the prismatic compass along one face of the frame coil, *i.e.*, in a direction parallel to the horizontal sides. It will be found that the edges of two opposite vertical sides of the framework can be brought into coincidence with the hair-line of the compass quite accurately. If the coil is set correctly the compass reading in this position should be equal to the value of the magnetic deviation at the place in question, plus or minus any correction for which the compass has been previously calibrated. The magnetic deviation is the angle between the magnetic and geographical meridians, and varies over Great Britain from about 14° in the South-East of England to 19° in the North-West of Ireland, the deviation being West of true North.

If the correct reading is not obtained in the above operation the coil stand should be gradually adjusted in the appropriate direction until the correct position has been found. The setting of the coil in this manner will result in the scale reading of 90° being obtained when the plane of the coil is in the geographical meridian, *i.e.*, pointing true North. Now the coil in this position will give a minimum or zero of signal strength for waves arriving at right angles to it, *i.e.*, from East or West (90° or 270°). When the D.F. coil is thus set in the above manner, and turned to the minimum position, the scale reading will indicate the true wireless bearing line for the signals being received without any further calculation. For additional accuracy in the above setting the coil can be rotated to a scale reading of 270°, and the compass observation repeated, sighting on the opposite side of the wooden framework.

The set being ready for use, the amplifier is switched on, and the condensers adjusted to tune in the required signals. If continuous waves are being received the oscillator must also be adjusted to give a suitable beat note. The conditions required for accurate bearing observations are good strong signals, as free as possible from any interference. In few cases can the signals be too strong, for it is to be remembered that near the minimum the signals are reduced to a small fraction of their maximum strength, and interfering signals, which would not affect reception in the maximum position, may become relatively strong at the minimum and seriously decrease the accuracy of observation. The interfering signals will, of course, have a minimum strength for a certain position of the coil, but in general they will come from a different direction to that of the required signals.

With the apparatus correctly adjusted, the lid of the screened box should be in position before a bearing is observed. The coil is then rotated to the position of minimum signal strength, and swung through a small angle to determine the scale readings at which an increase in the strength of signals in the telephones is just detectable on either side of the true minimum. The mean of the

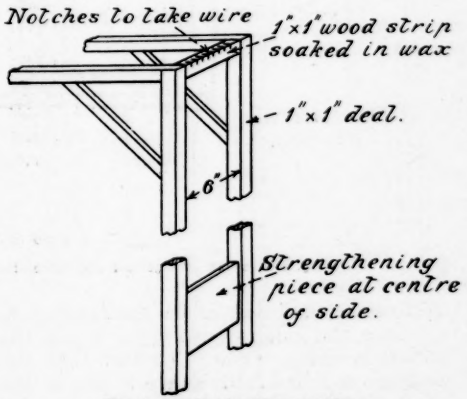


Fig. 4—Details of coil construction.

two readings so obtained is the observed bearing in this position, and half the swing is the "accuracy" of the observation.

To complete the determination the coil should be rotated through 180° and the above observation repeated to obtain a "reciprocal" bearing, *i.e.*, 180° away from the "direct" bearing of the transmitting station under observation. As these two will not usually be exactly 180° apart, the direct and reciprocal readings are added together, 180° subtracted, and the result divided by two to deduce the mean observed bearing.

(d) Method of Improving the Accuracy of Readings.

Probably the first desirable point in the operation of such a direction finder is to

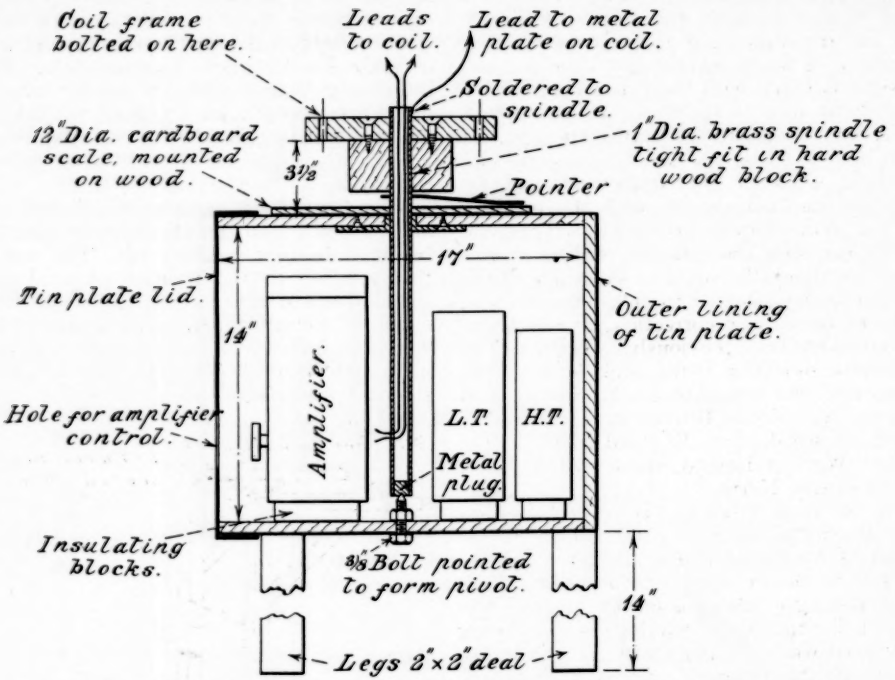


Fig. 5—Showing arrangement and dimensions of the case containing amplifier and batteries.

improve the sharpness of the minimum, *i.e.*, to reduce the angle of swing by which the bearing is determined. The fact that the minimum is not already sharp is due to the coil acting as an antenna with capacity connection to earth, as already explained.* The explanation there given suggests that if the capacity to earth of the input terminals of the amplifier can be equalised, this antenna effect of the coil, although still acting, will not give rise to any signals passed through the amplifier to the telephones. This compensation of the antenna effect can be carried out by the connection of a small variable condenser between the grid of the first valve and earth. The lead to earth should be as short as possible, passing directly below the box. For portable work a suitable "earth-pin" may be used, pushed into the ground near one leg of the set, but an excellent alternative is found in the use of a large plate of copper placed flat on the ground, and upon which is stood the whole set. In either case, the metal screening box should be connected to this "earthy" terminal. In the taking of a bearing, the coil is swung slowly about the minimum position, while the compensating condenser is adjusted until the setting to give the sharpest minimum or zero has been found. In many cases it will be found that this method will enable the observed bearing to be located with an angle of swing as small as 0.1°. With such sensitivity it will usually be found that a slight movement of the operator will alter the necessary adjustments, since he is contributory to the antenna effect ***via*** the telephone receivers. In taking the reciprocal bearing a fresh adjustment of the compensating condenser will in general be necessary, and the setting also varies for the observations made on other signals and wave-lengths.

Another method of improving the accuracy

* See EXPERIMENTAL WIRELESS, January, 1924, Vol. I, p. 194.

of the bearing observation is that which was actually adopted in the set described above. A "capacity" plate of tinfoil or copper gauze is mounted on the top horizontal part of the coil frame immediately underneath the winding, as shown in Figs. 1 and 6. A lead from this plate is brought straight down across the centre of the frame, and connected to the metal screen of the apparatus box, which itself need not be earthed. This arrangement will be found to greatly decrease the antenna effect of the coil, and result in a considerable sharpening of the signal minima, although these will not be so sharp as those obtainable with the compensating condenser. By such means, however, bearings can be observed to an accuracy of 1° or 2°, which is as close as many practical applications, and certain other defects inherent in direction finders, warrants at the present time. This last method, moreover, has the great advantage of not requiring any adjustment whatever in observing on signals on different wave-lengths.

Should the above methods not result in the production of sufficiently sharp minima for observation purposes, under favourable conditions, an undue amount of "direct pick-up" on the amplifier and connecting leads should be suspected. A thorough inspection of all the parts of the apparatus forming the screen should be made, particularly ascertaining that all unnecessary holes and cracks are eliminated, and that all joints are thoroughly sweated, and preferably covered with a thin strip of tinplate.

(e) Observations and Experiments to be carried out.

One of the most important experiments to be carried out with such a direction finder when constructed and working is to ascertain the reliability of it as a portable direction finder. To do this an open site should be chosen as the field of operations, this site being quite free of trees, overhead wires, streams or river, and buildings for a radius of at least two hundred yards. The apparatus should then be erected in the manner described and observations of bearings taken on transmissions from the nearest station within the wave-length range of the instrument. The observations should be repeated at five-minute intervals for about half an hour. If the transmitting station is reasonably near, and the observations are made near mid-day, the bearings so obtained should agree within one or two degrees, and by taking the mean of the set of readings a fairly accurate value of the observed bearing is obtained. The whole apparatus is now transported a distance of fifty or one hundred yards and the operations repeated. Except when the transmitter is within five miles such a change in position makes no appreciable change in the true bearing, and the mean observed bearing, therefore, should be the same as before. If this is not the case, it means either that the setting of the coil by

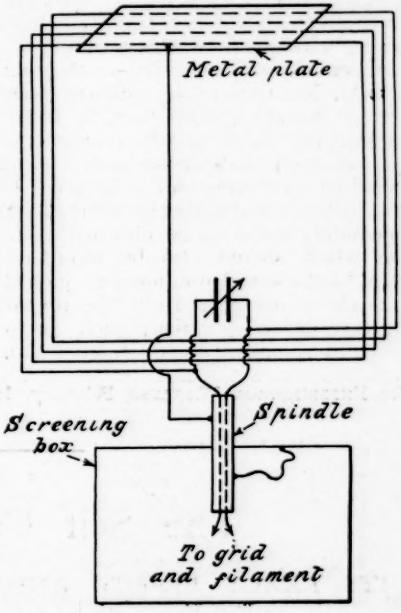


Fig. 6—Connections of the frame to amplifier.

compass is not accurate or that an error of observation is involved. With continued repetition of these operations, it will be found that skill is acquired in the taking of accurate bearings, and that the observations can be repeated to within 2° or 3°, but not closer than this.

Having established the reliability of the set for the observation of bearings, it may then be used for the determination of the nature and magnitude of the errors introduced by various local conditions, such as

trees, buildings, telegraph wires, railway lines, and tuned coils and aerials. It was, in fact, with such a portable set that the majority of the results described in Part II* of this article were obtained. There is still much room for useful experimental work in this direction, particularly in the investigation of the effect of change in wave-length on the errors introduced by any one or more fixed local disturbances.

Probably the most attractive field for investigation with this type of direction finder, however, is that of the study of variations in bearings. With the apparatus set up and correctly oriented in some fairly permanent location, two or three transmitting stations within the working range of the instrument should be selected for observation purposes. Readings of the apparent bearings of these stations should then be taken in rotation, the cycle of observations being repeated at intervals of five or ten minutes, Having once determined the apparent bearing of each received signal, its value should be immediately noted on an observation form. upon which should also be recorded the nature of the signal minimum as judged by the angle of swing, and also the prevailing conditions of observation, such as interference by signals and atmospherics, etc. If such a series of systematic observations is made for a period of one or two hours at a time, and repeated at regular intervals, or from day to day, several interesting facts will be observed, the salient points of which have already been described in Part II* above. Although it is not always the case, it will frequently be found that when the observed bearings are seriously different from their true value, the minima are also very flat, making an accurate observation difficult to obtain. In some cases it will be found that there is no detectable change in the intensity of the signal as the coil is rotated through 360°. While most of these effects can be accounted for in a qualitative manner on the existing theories of electro-magnetic wave propagation, there is still a great scarcity of accurate quantitative data on the subject. A final suggestion which may be given to the experimenter who is sufficiently interested in this matter to carry out serious investigations, is that the observation of variations of bearings might be combined with simultaneous observations of the "fading" of the signals received. Some simple method of measuring the strength of the signals should be adopted, the signals being received either on a separate aerial or on the direction finder with the frame coil placed in the maximum position, *i.e.*, with its plane parallel to the direction of the transmitter.

* See EXPERIMENTAL WIRELESS, February, 1924.

The Self Capacity of Coils.

ITS EXACT EFFECT AND WHERE IT MAY BE IGNORED.

By J. H. REYNER, A.C.G.I., B.Sc., D.I.C.

THE self capacity of a coil, as is well known, is the resultant effect of the capacity between the various turns of wire in the coil, and it is generally considered highly undesirable and to be avoided at all costs. Consequently there are on the market numerous forms of low capacity coil which have been described from time to time, and are familiar to every radio enthusiast.

Now, although the reduction of self capacity has become almost a fetish, it is, in many cases, of secondary importance only. It is proposed in this article to indicate the exact effect of self capacity, so enabling the experimenter to decide what precautions should be taken.

Values of Self Capacity.

The value of the self capacity is in most cases very low. The problem has been investigated by many eminent scientists, notably Professor Howe (*Journal I.E.E.*, December, 1921), and Professor Morecroft (*Proc. I.R.E.*,

August, 1922) and the results in some particulars are by no means consistent.

It appears that for single-layer coils, the self capacity is about ·6 r (where r is the radius in cms.), irrespective of the length and number of turns. For multi-layer coils the value is somewhat higher, and may have a value of up to 1·5 r. In any case, the self capacity is of the order of from 5 to 15 micro-microfarads, which is smaller than the stray

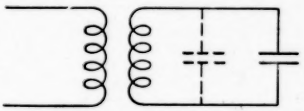


Fig. 1.—The E.M.F. is introduced in the coil itself.

capacities in the circuit. With an ordinary valve and four-pin socket the capacity between grid and filament is of the order of 20 micro-microfarads, in addition to which there are the capacities of the leads, switches, etc., so that in general the self capacity of the coil is of secondary importance.

Effects of Self Capacity.

Turning now to the effects of self capacity, the first consideration is the position of the coil in the circuit. It will readily be understood that there are two possible conditions:

(*a*) When the e.m.f. in the circuit is introduced in the coil itself;

(*b*) When the e.m.f. is introduced in series with the coil.

Fig. 1 shows the condition (*a*). It will be observed that in this case the only effect of the self capacity is to increase the tuning capacity across the coil.

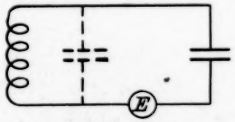


Fig. 2.—The E.M.F. is introduced in series.

Now the energy in the circuit is usually limited, being given by $W=\frac{1}{2}CV^2=\frac{1}{2}LI^2$. Where the voltage is required to be a maximum, as in receiving and detecting circuits, the capacity must be made small and the inductance large.

The effect of self capacity in the coil will be to increase the minimum of tuning condenser, and so to reduce the range. Whether this is permissible or not depends on circumstances, but in many cases it does not constitute a serious disadvantage.

Where a large current is required, on the other hand, C is made large, and in this case the self capacity, neglecting losses, has no detrimental effect.

The second condition is illustrated in Fig 2, the E.M.F. being in series with the coil. Now the apparent resistance to an external E.M.F. of an inductance and condenser in parallel varies with the frequency, and increases enormously as the resonant frequency is approached.

The actual value of the apparent resistance R is given by

$$R=\frac{R_0}{(1-w^2LC_0^2)}$$

where L = inductance
C_0 = self capacity
R_0 = true resistance of the coil.

Fig. 3 gives a curve showing the ratio of R/R_0 in terms of the ratio λ/λ_0 being the wavelength used, and λ_0 the natural

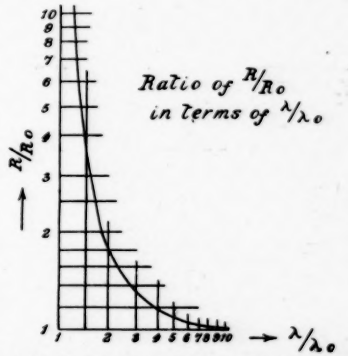


Fig. 3.—Ratio of resistances expressed as ratio of wave-lengths.

wave-length of the coil (*i.e.*, the wave-length to which the coil tunes without any added capacity).

It will be seen that, even at a wave-length five times the natural, the increase of resistance is still appreciable and it is in a case like this that a low capacity coil may be used with advantage. Circuits of this type are frequently met in practice, Fig. 4 being a case in point. Here L would be made high, and C small to obtain the maximum voltage on the detector. Unless a low capacity coil is employed, the natural wave-length might only be one-third or one-fourth of the working

wave-length, in which case the extra resistance effect would more than neutralise the gain in signal strength obtained by using a small tuning condenser. Such a circuit is often employed for extending the wave-length of a given set.

Tapped Coils.

Self capacity is responsible also for the dead end effect noticeable when tapped inductances are employed. E.M.F. is induced in the overhanging portion, and the circuit is closed by the self capacity as in Fig. 5. Moreover, as there is an auto-transformer effect, the voltage across the coil may be several times as large as that across the tapped part. For this reason a coil should never be tapped more than half-way down.

Energy is, of course, absorbed from the main oscillating circuit, so causing the

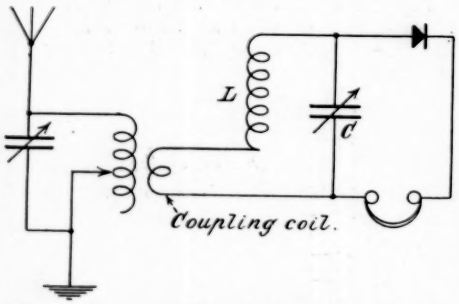
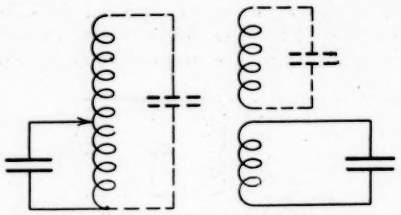


Fig. 4.—L should be high and C small to give maximum voltage on the detector.

apparent resistance to increase. The effect is particularly severe if the working wave-length is near the natural wave-length of the whole coil (including the overhanging turns). In this case the circuit will be found to have two resonant frequencies, and may change from one to the other with a jump. Where the overhanging portion is large it is better to short circuit the turns rather than leave them open, as less energy is absorbed and the double frequency effect is obviated.

The trouble may be avoided to a large extent by completely isolating the unused turns, as in Fig. 6. The only danger here is if the second coil is anywhere near resonance with the main coil, but this is not such a likely contingency. Trouble may arise, however, in "universal" receivers having all coils from 300-30,000 metres in the same set. Marked "flat spots" are apt to be found when the coil in use comes into tune with some higher valued coil, which is resonating through its self capacity.



Figs. 5 and 6.—In Fig. 5 self-capacity closes the overhanging portion, and this effect can be reduced by isolation as shown in Fig. 6.

Losses.

An aspect of the question which is not always considered is that of the losses due to self capacity. The electric strain passes through the former of the coil and the insulation of the wire. In particular, cheap paper formers, imperfectly dried, are liable to cause heavy losses. End connections are another feature which deserve attention; the ends of the coil are often brought to plugs in a socket of insulating compound. If this is of poor quality an increase of 10 per cent. in the effective resistance may result.

In general, end connections deserve attention. A construction such as is shown in Fig. 7 will more than double the self capacity.

Variometers and loose couplers in particular should be wound on high grade formers to

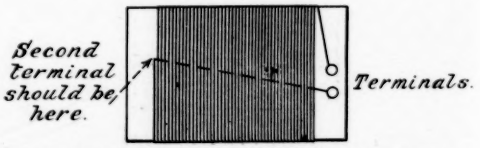


Fig. 7.—The arrangement of the leads shown above will more than double the self-capacity of a tuning coil.

avoid loss, since the capacity between rotor and stator has the stator former for a dielectric. From this point of view the types of variometer employing internally wound stators are preferable.

High-Frequency Resistance.

Many experimenters seem to imagine that the determination of high frequency resistance necessitates the use of complicated apparatus. However, by the simple methods described below fairly accurate results may be obtained.

IN the course of their many different experiments, both in transmitting and in receiving, most genuine experimenters have probably asked themselves the question, "Now I wonder what the effective resistance of that coil really is?" They know that by using our old friend Wheatstone's bridge, or even by simply referring to wire tables, that they can easily find out, at any rate near enough, what the resistance of their coil is to direct current, but it is, or should be, a well-known fact that that does not help us much when we are working at a frequency of, shall we say, 10^6 ~.

Now, the average experimenter imagines—and, I think, quite rightly imagines—that it is a difficult laboratory experiment to determine accurately the resistance of a coil of wire at such a high frequency as a million. But at the same time it would be extremely helpful to the experimenter if he could simply determine the approximate resistance of his coil and so find out if its resistance was sufficient to damp his circuit seriously. It is, therefore, the object of this article to give a brief outline of some of the methods used to determine high-frequency resistance, with a few practical details where the method is suited to our purpose. Where the method obviously requires expensive instruments and elaborate apparatus there is obviously no need to give "full instructions."

Method I.—Calorimetric.

Perhaps the most obvious effect of a current flowing in a coil of wire, and one that is quite independent of frequency—apart, of course, from resistance variation—is that the current heats up the wire.

Now, if we have a coil of wire of H.F. resistance R_x, the unknown which we wish to determine, we know that, with a current I flowing in it, the power P lost in heat is I^2R_x. If, then, the coil is placed in an oil bath, and the temperature rise for a given period noted with the current I flowing, P may be determined, and if I is accurately known at the frequency we may easily calculate R_x.

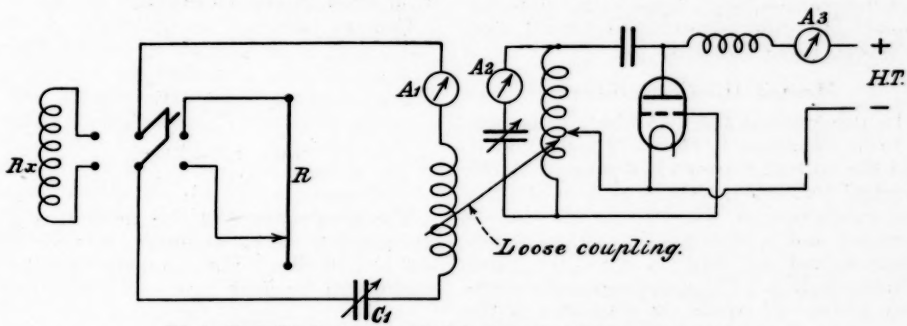


Fig. 1.—Illustrating the arrangement of the circuit for the substitution method.

An improvement on this method, and one more suitable to our purpose, is to determine P electrically; that is to say, obtain a given rise of temperature of our oil bath both with H.F. and D.C. current, and then equate the two losses. If this is done, and R_1 and I_1 denote the D.C. values of R_x and I, then we may say—

$$R_x = \frac{R_0 I^2}{I^2}$$

If a suitable calorimeter is available, and the coil is not too large, this method might easily be used by the experimenter. With a little ingenuity the expansion of the air in a closed vessel containing the coil may be used to indicate the watts dissipated, this being simpler than using a thermometer and an oil tank. The chief errors likely to

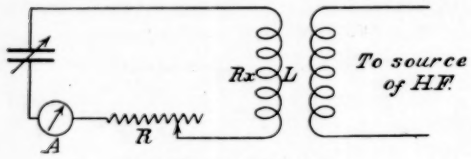


Fig. 2.—Circuit for Method III.

arise in this method are those due to unaccounted losses of heat and also that assumption that all the energy is lost in heat. At high frequencies, with large coils, quite an appreciable error might be introduced, due to energy being radiated.

Method II.—Substitution.

In this method the coil whose resistance is to be measured is placed in some circuit and the current through it measured at the required frequency. Then, without altering the conditions of the circuit, the coil is removed and a standard known resistance inserted and adjusted to give the same current reading. Then, obviously, the resistance of the coil equals the resistance of the standard inserted.

This method has really been described already by the author in his paper on "Antenna Constants."

This method is by far the simplest *on paper*, but the practice is a very different story. The chief difficulty is to keep the conditions in the circuit in which the coil is inserted *exactly* the same in both cases, and also to obtain a standard resistance which is constant at all frequencies and continuously variable.

If, however, care is taken in the construction of a variable straight-wire resistance, results of a fair accuracy may be obtained if the resistance is not too high.

In Fig. 1 is given a suggested circuit for this method.

In order to test if the conditions are the same in both cases, the change-over switch is moved from one side, and if the circuit is kept in resonance by the variable condenser C no change should take place in either A_2 or A_3 when R is substituted for R_x.

The frequency may, of course, be measured by means of a wave-meter loosely coupled to the "driver" circuit. The resistance R may be constructed by stretching a long, thin Eureka wire along a board and calibrating it previously either from tables or by means of a Post Office box.

Method III.

Another method which may be really included under the last head is the Resistance Variation method. In this case a circuit such as that shown in Fig. 2 is used. In this case the unknown and the standard are both connected in the circuit. Two readings of the current are obtained in A, firstly with R at zero value I, and then with a resistance R_1 inserted, giving a value I_1.

Then we have—

$$I = \frac{E}{R_x}$$

$$I_1 = \frac{E}{R_x + R_1}$$

$$\text{hence } R_x = \frac{R_1}{\frac{I}{I_1} - I}$$

The disadvantage of this method is that an accurate H.F. ammeter is necessary, but a "Moullin" H.F. ammeter (see later) might well be used here.

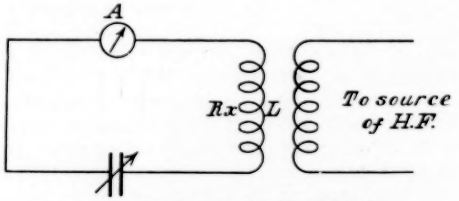


Fig. 3.—The arrangement for Method IV.

Method IV.

In this method no standard resistance is used, but the reactance of the circuit is altered and two readings obtained (Fig. 3).

An observation of A is made with the circuit in resonance. We then have—

$$I_r^2 = \frac{E^2}{R^2}$$

A second reading is then obtained with

the circuit when the circuit is slightly out of resonance I_1^2, in which case—

$$I_1^2 = \frac{E^2}{R^2 + X_1^2}$$

and hence $$R = X_1 \sqrt{\frac{I_1^2}{I^2 - I_1^2}}$$

The value of X_1 may obviously be calculated from the values of C and L, and hence R is obtained.

This method is not easy to manipulate, involving, as it does, an accurate knowledge of C and L, also a very constant value for E, and hence is not really suited to our purpose.

Method V.

This method, due to Prof. E. Mallet, M.Sc., is really also a reactance variation method, but is one which the author has personally used with a certain amount of success. If we consider two coils, as in Fig. 4, let us suppose that L_1 carries a current I_1 producing an E.M.F. E_1 across the coil; and let us suppose L_2 is coupled to L_1, but not in resonance with it, such that the mutual inductance between the two coils is M'. Then there will be a P.D. E_2' across L_2, and, neglecting the self-capacity of L_2, the E.M.F. induced in L_2 will equal the P.D. E_2'. Now, by connecting a crystal detector and galvo. across L_2, a reading on the galvo. may be obtained proportional to E_2'.

Now we may say—

$$E_2'' = \omega M^1 I_1$$

In case (*b*) the circuit L_2 is brought into resonance with L_1, the frequency being kept constant. Then the P.D. across the coil will now be E_c, and will not be equal to the E.M.F. induced E_2''. If the reading on the galvo. is kept constant in both cases we may say—

$$E_c = E_2^1$$

$$E_c = \frac{I_2}{\omega C}$$

$$I_2 = \frac{E_2''}{R}, \quad \text{when R is the vector of circuit } L_2\ C_2.$$

$$\text{Then } R = \frac{E_2''}{I_2} = \frac{\omega M'' I_1}{Ec\,\omega C} = \frac{M'' I_1}{\omega M^1 I_1 C}$$

$$= \frac{M''}{M^1} \cdot \frac{1}{\omega C}$$

Hence we see that if we first calibrate the mutual between the coils L_1 and L_2 either by experiment or by calculation, if we know, as we may easily do, the value of C and W, the value of R may be easily calculated.

This method works extremely well provided the natural frequency of the coil L_2 is not approached. Obviously, if the frequency used is brought anywhere near to the natural of L_2 the self-capacity of the coil can no longer be neglected and the method fails. I had better, perhaps, mention, to save unnecessary argument, that this method is obviously only approximate, as the statements just made are not absolutely true, but with the above reservation they are good enough for ordinary work and give quite good results. In practice, the author checked readings obtained for a coil by this method by inserting a small non-

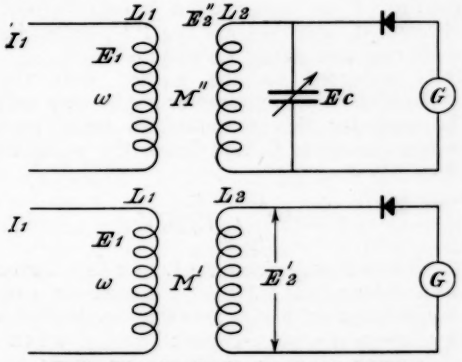


Fig. 4.—Illustrating the circuits used for Method V.

inductive resistance (3" No. 40 Eureka) and checking its resistance by subtraction.

The obvious disadvantage of this method is the necessity for a calibrated mutual inductance, but, as the reader has probably already gathered, in all these methods there is always a snag somewhere!

Method VI.—Potential Drop Method.

In this last method advantage is taken of that law which comes into almost everything electrical one can think of, namely, Ohm's law.

We know that in a D.C. circuit—

$$I = \frac{E}{R}$$

and that in an A.C. circuit—

$$I = \frac{E}{\sqrt{R_2^2 + \omega^2 L^2 + \frac{1}{\omega^2 C_2}}}$$

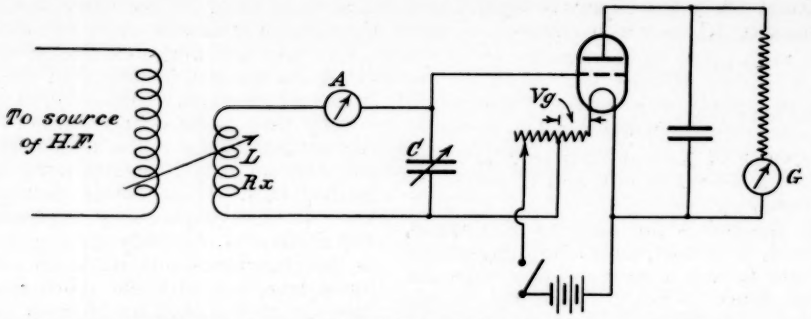


Fig. 5.—The resistance is here measured by the potential drop method by the apparatus shown above.

Now, if we wish to measure the resistance of a coil of wire of value R_x ohms and L henries, if we can pass a known current through it, and measure the P.D. across its ends, we can easily determine R.

It occurred to the author that the "Moullin"* H.F. voltmeter might very well be used for this purpose. In small coils we may neglect C, and hence the equation becomes—

$$I = \frac{E}{\sqrt{R^2 + \omega^2 L^2}}$$

Now, we may calculate L to a fair degree of accuracy from tables or else measure it on an inductance bridge; we may easily find ω by means of a wave-meter; hence, if we can determine E with sufficient accuracy we have a simple method of measuring R.

A suggested circuit is given in Fig. 5.

In this arrangement the valve grid is made about 1·6 volts negative to reduce the grid damping to a negligible amount. Advantage is then taken of the curvature of the grid-volts anode current curve of the valve.

The readings of the galvo. in the anode circuit of the valve may be obviously first calibrated on D.C., so that a direct reading of volts may be obtained. A current is then obtained in A of value I_1, and P.D. read off on G., V_1.

Then we have—

$$I_1 = \frac{V_1}{\sqrt{R^2 + \omega^2 L^2 + \frac{1}{\omega^2 C^2}}}$$

Now, if we bring the circuit L_2C into resonance with the frequency of the supply, we know that—

$$\omega L = \frac{1}{\omega C}$$

$$\text{hence } I_1 = \frac{V_1}{R}$$

$$\text{or } R = \frac{V_1}{I_1}$$

In this way we obtain a very simple method of obtaining the value of R. The only apparatus necessary is a H.F. ammeter, such as a hot wire ammeter—which, although notoriously inaccurate, may be calibrated against a standard, a receiving valve and a D.C. volt-meter for calibration purposes.

Perhaps the simplest method of arrangement would be to have a change-over switch so that a grid battery and voltmeter could be brought into action after each reading and the galvo. need not be actually calibrated in volts.

This method completes a very rough survey of the main methods of H.F. resistance. It is not proposed to deal in this paper with the measurement of condenser resistance.

It is left to the enthusiastic experimenter to decide which method he will use, but, on the whole, the author would recommend the last method as requiring very little apparatus, and which, with care, should give quite good results. Of the other methods perhaps the resistance substitution method is the next best, but, as has been mentioned before, great care must be exercised to keep the conditions constant throughout. In the case of the last method, if a reliable H.F. ammeter (if such a thing exists) is not

* See *Wireless World*, 1922, x, 1; also paper read before Inst. Elect. Engrs., December, 1922, by E. B. Moullin.

available, the same principle as that used in measuring the P.D. across the coil might also be used for measuring the current through. In this case a small known non-inductive resistance could be inserted and the drop across the ends of it measured with a second valve. This again could be calibrated on D.C. This last is only a suggestion, and has not been tested by the author.

In conclusion, the author would be very pleased to hear from anybody who obtains results from any of these methods, as the subject is an extremely interesting one, and more practical data is very necessary.

"Howling" in Resistance Amplifiers.

ITS CAUSE AND ELIMINATION.

By F. M. COLEBROOK, B.Sc., D.I.C., A.C.G.I.

Probably every experimenter, when building a capacity coupled amplifier, has been troubled by howling. The cause and method of elimination are discussed below.

FROM a theoretical point of view the resistance-capacity coupled amplifier (the usual arrangement of which is illustrated in Fig. 1) possesses many attractive features, the chief of which is the relative independence of frequency of the amplification it produces. This applies over the whole range of audible frequencies, and even at high frequencies this uniformity of performance can be maintained up to about 3,000 metres without much difficulty. For wave-lengths shorter than this there is, unless special precautions are taken, a very marked falling off in efficiency, attributable to inter-electrode and other stray capacities.

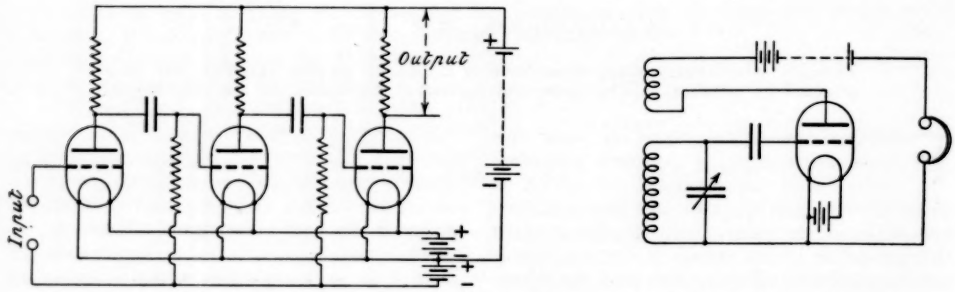
From a practical point of view, however, the resistance capacity arrangement has certain definite disadvantages. Some of these, as, for instance, the wasteful fall of potential in the anode resistances, and the comparatively low amplification per stage, are inherent and unavoidable, and must be written off against the advantages of the system. Another serious defect is the one which forms the subject of this paper, namely, the internal instability of the amplifier, the effect of which is to produce, at best, a loud rushing sound, and at worst, a harsh and particularly discordant howling noise in telephones connected to the output end. This troublesome tendency is particularly marked in cases where the input circuit is capable of oscillation at radio frequencies.

It had long seemed probable to the writer that this effect would, on investigation, be found to be associated with the unsymmetrical nature of the charging and discharging paths of the grid condensers. Referring to Fig. 1, it will be seen that if by any means the plate of the grid condenser, which is connected to the grid, acquires a charge which makes its potential positive with respect to the negative end of the filament, this charge can disappear by flowing as an electric current through two paths, one being the grid leak and the other the direct conduction between the grid and the filament (*i.e.*, a flow of electrons from the filament to the grid). If, on the other hand, this plate of the condenser becomes negatively charged with respect to the negative end of the filament only one path is available for its discharge, namely, the grid leak, since electrons will not pass from the grid to the filament.

It was quite by chance that the writer hit upon a single-valve circuit which demonstrated that the low frequency howl of resistance amplifiers was definitely associated with this asymmetrical charge and discharge condition, and which indicated the means by which he has since succeeded in eliminating, or at least, very greatly reducing, this tendency.

The circuit is illustrated in Fig. 2 and is seen to consist essentially of an oscillatory circuit connected through a condenser of

about ·0002 microfarads to the grid, there being in the anode circuit a reaction coil sufficiently closely coupled to the oscillatory circuit to cause and sustain oscillations in the latter when the grid condenser is short-circuited. In the case in which the effect to be described was first noticed the coils actually consisted of two equal windings of three turns each on an eighteen-inch square frame aerial, but the actual type of coil is non-essential, though the effect is more pronounced at short wave-lengths (300 to 1,000 metres). On listening with the telephones it will be found that for a considerable range of variation of the tuning condenser there



Figs. 1 and 2.—On the left is shown the normal arrangement of a resistance coupled amplifier, while on the right is a circuit illustrating the origin of howling.

can be heard a succession of loud clicks occurring at quite regular intervals of about a second or so. Towards either end of the tuning condenser range in which these clicks are heard their frequency increases very rapidly, and by careful adjustment of the tuning condenser it will be found possible to speed them up until the effect is that of a continuous growl, a noise very similar in character to the usual low frequency howl.

Now it can be shown that each of these clicks is associated with the sudden starting and stopping of high frequency oscillations in the oscillatory circuit. This fact can be demonstrated by means of an ordinary heterodyne wavemeter. Having adjusted the circuit to the condition in which clicks are occurring at a fairly slow rate, say, one or two per second, the heterodyne wavemeter is brought into the neighbourhood of the oscillatory circuit. It is then tuned to the frequency of the latter, when it will be found that the clicks change slightly in character. They occur at the same rate, but each click finishes with a sort of squeak, the pitch of which depends on the degree of closeness of the tuning of the wavemeter. This squeak is clearly the momentary heterodyne beat between the wavemeter oscillation and the sudden brief oscillation of the valve circuit.

The reason for this interrupted state of oscillation is not difficult to see. In its initial condition, the plate of the condenser, which is connected to the grid, takes up an equilibrium potential (about −2 volts), which is just sufficient to prevent the flow of any electrons from the filament to the grid. When the oscillatory circuit breaks into oscillation the grid connected condenser plate assumes a positive potential once in every cycle, with the result that more electrons are drawn to the grid. The only way of escape for these electrons is through the very high resistance path offered by the insulation of the condenser and through the insulating material of the valve-holder. The rate at which they can so escape will be very much slower than the rate at which they accumulate on the grid during the positive half-cycles of the oscillations. Consequently, as long as the oscillations persist the mean potential of the grid becomes more and more negative. Finally the grid becomes sufficiently negative to stop the oscillations. After this point is reached the grid will become less and less negative owing to the leaking away of the charge through the various insulation paths until once more a point is reached at which the oscillations will re-commence, a click in the telephones being produced by the

consequent sudden change in the mean anode current flowing through them. This explanation is not invalidated by the fact that it involves something in the nature of an inertia effect, the oscillations persisting at a lower grid potential than is required to start them, for this is a fact of frequent occurrence in valve generation.

The frequency of the clicks clearly depends on two main factors. One of these is the effective negative resistance of the grid circuit—in other words, the force tending to set the grid circuit in oscillation. It is for this reason that the frequency of the clicks was found to depend on the setting of the tuning condenser. The other important factor is obviously the resistance of the leakage paths for the discharge of the grid condenser. Lowering the resistance of these paths will tend to increase the frequency of the clicks. This can be confirmed by inserting a grid leak of high value, say, five or six megohms, when it will be found that for certain settings of the condenser a howl of unmistakably the same character as that associated with the resistance capacity amplifier can be produced.

To relate this to the actual case of a resistance-capacity amplifier it is only necessary to remember that the input grid circuit of a properly designed amplifier of this type will nearly always have a negative effective resistance, even when there is no externally applied reaction. It appears that the stray capacities associated with the components of the amplifier are quite sufficient to produce a marked reactive effect. This is specially the case when the operator is wearing telephones connected in the output end. The conditions are, therefore, essentially the same as those obtaining in the experimental circuit described above, and the tendency to howling can reasonably be attributed to the same cause.

The remedy suggested by this analysis is the removal of the asymmetry in the charging and discharging paths of the grid condensers. This can be done by using grid leaks of sufficiently low resistance to ensure that there shall be no appreciable change of mean grid potential even if the input circuit does oscillate. This is preferable to preventing the oscillation of the grid circuit, as it is in nearly every case desirable that the input circuit shall have as low a resistance as possible, while in certain cases the oscillation of the input circuit may be essential for the purpose to which the amplifier is being applied.

The value chosen for the grid leaks should be the highest consistent with the requirement indicated above. Apart from any other consideration, the grid leak resistance should be as high as possible compared with the impedance of the grid condenser for the frequencies at which the amplifier is to operate. There is, however, another reason why this resistance should not be brought lower than is found necessary to maintain the grid potential at a constant value. This reason lies in the fact that whatever resistance is connected between the grid and filament of any given valve is virtually a shunt to the resistance inserted in the anode circuit of the valve which precedes it. The efficient operation of a resistance amplifier requires that the anode resistances shall have as high a value as is practicable compared with the internal (slope) resistance of the valve. For instance, assuming values 50,000 ohms and 10 for the internal resistance and the voltage factor of the valve, an inserted anode resistance of 100,000 ohms will give a theoretical

voltage amplification of $1 + \frac{10}{\frac{50{,}000}{100{,}000}}$, *i.e.*, 6·66 per stage of amplification. If, however, the grid leak of the following valve has a resistance of only 100,000 ohms the effective anode resistance will be reduced to 50,000 ohms (the two resistances of 100,000 ohms in parallel) and the theoretical amplification factor per stage will be reduced to $1 + \frac{10}{\frac{50{,}000}{50{,}000}}$ *i.e.*, 5.

The writer has found in practice that a very suitable compromise is the use of grid leaks of about one quarter of a megohm. This arrangement affords a very great gain in silence and stability of operation, with no appreciable loss of sensitivity.

The Telephone Receiver and its Application to Wireless Circuits.

By ALEXANDER J. GAYES.

Almost invariably those engaged in experimental work relating to the reception of weak signals confine adjustments to the amplifier and rectifier circuits and simply employ a good pair of telephones In the following article the conditions giving maximum sensitivity are discussed and suitable arrangements of circuits are shown.

THE successful reception of wireless signals, either Morse, speech or music, depends to a large extent upon the accuracy and efficiency with which the undulating currents are finally converted into sound energy. In view of this, one would

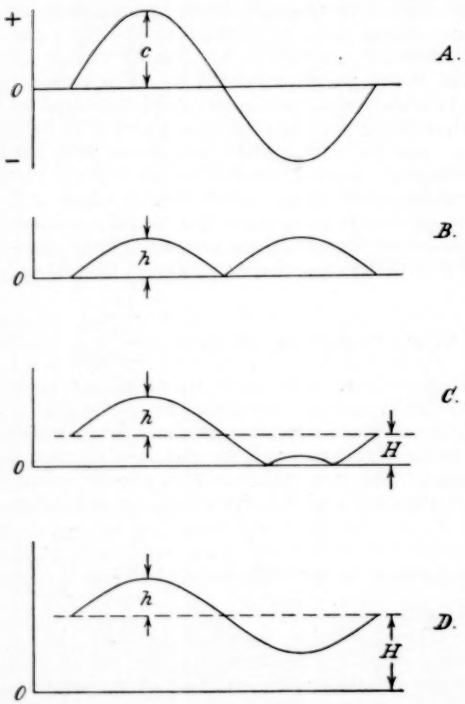


Fig. 1.—Illustrating the conditions obtaining in a telephone receiver.

expect to find more attention devoted to the perfection of telephone receivers as applied to wireless apparatus than is usually given to this vital link in the chain of communication. The telephone engineer has, of course, made an exhaustive study of the receiver, and has produced an article which, from his point of view, may be open to very little improvement, and it is this receiver which, in the majority of cases, is used by the wireless expert after certain modifications in the way of windings. There are exceptions, as, for example, in the reed form of receiver, but the magnetic principle of this being similar to that of ordinary receivers, much of what follows will apply equally to the reed pattern receiver.

It is proposed now to make a cursory study of the problems associated with the design of the receiver to find whether, in adapting the receiver to wireless circuits, full advantage is being taken of the points so carefully introduced by the designer. The first fact apparent to the observer is that receivers differ considerably in size. In the larger forms, generally referred to as loud speakers, receivers have secured their full share of attention from the experimenter, but it is possible that a detailed study of the functioning of telephone receivers in general may lead to improvements as the result of a better understanding of the principles involved. In the case of head receivers there is certainly scope for the experimenter, and particularly for those who are interested in long distance reception, as often the utmost efficiency is necessary under the particular conditions existing at the moment. This at once brings in consideration of the size of the receiver. One would not expect a small diaphragm to emit a large volume of sound, and neither would one select a large receiver with heavy parts to respond to very feeble sounds. It becomes necessary, therefore, to divide receivers into two classes, loud speakers and the others, which are usually of the head

receiver type. It is proposed to consider here only the latter, as the design of the loud-speaking receiver is a subject in itself. Referring, then, to head receivers only, we are again faced with a division; those for ordinary concert use, and those destined for the reception of weak signals and feeble speech or music.

The receiver for concert use—that is, one which is given electrical energy of sufficient magnitude to reproduce sound of approximately the volume usual with line telephones, does not call for great attention at the moment. The conditions in this case are so nearly those obtaining with line telephones that a receiver, as designed and produced by any one of the well-known manufacturers of telephone receivers, will function so perfectly as to leave little room for improvement—that is, of course, provided it is properly applied to the circuit. This proviso is added intentionally, and refers chiefly to the fact that in the majority of wireless circuits the H.T. supply is conducted *via* the head receivers, and is varied in magnitude to suit the valve and not the receivers. This is a condition which would shock a critical telephone engineer. If the magnitude of this H.T. current be known, and could remain unaltered, the position would not be so acute as steps could be taken to allow for its polarising effect. The importance of securing the correct value of the magnetising force of the polarising magnets is often overlooked, and it is interesting to study for a moment the principles of polarisation. In the case of the receiver, which we will call the "sensitive" receivers, to be used for weak signals and feeble speech, the intensity of the polarisation is of considerable importance, and as it is in these that the highest possible efficiency is desired, the following comments are intended to apply more directly to this pattern.

In dealing with the theory of operation of the receiver, or in attempting to discuss the effects of a slight change in current in the receiver circuit, one must go cautiously, as the effects are complicated. It will be realised that the degree of permeability of the various components of the magnetic circuit will determine the amount of change of flux, and the instant the diaphragm responds, the reluctance of the magnetic circuit will be changed, which in turn again affects the flux. This latter change is itself complicated owing to a possible composite effect of the electro-magnetism, and the so-called permanent magnetism of the polarising magnet. When considering the effects on the diaphragm the two "square" laws come more or less into operation. The first, that the pull on an armature is proportional to the square of the intensity of the magnetic force in the air gap between the armature and the pole, and the second, that the force of attraction between two poles is inversely proportional to the square of the distance between them. Without going so deeply into the matter, however, it will be sufficient now to state that an increase in current through the

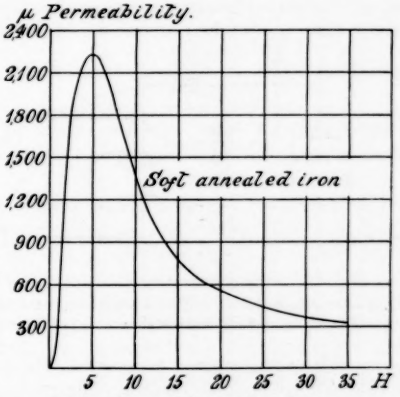


Fig. 2.—Permeability curve for soft iron.

receiver windings will produce an increase in the pull on the diaphragm, which in consequence will move slightly towards the magnets. Now the component of the total current passing through the receiver, effective in moving the diaphragm, may, in its simplest form, be represented by a sine wave curve as in diagram A, Fig. 1. Such current would, in the case of a non-polarised receiver, produce motion in the diaphragm roughly in accordance with a flux variation, as indicated in diagram B, Fig. 1. This is chiefly of theoretical interest, but in passing, it might be mentioned that mathematically it would appear that such a receiver would produce a note an octave higher than that represented by the impressed wave, and Herr J. W. Giltay claims to have proved this experimentally. Diagram C, Fig. 1, is

of more practical interest. Here is shown the possible motion of the diaphragm or armature where a certain amount of polarisation exists. In this case the polarisation represented by H is small compared with the magnetic effect of the speech current represented by *h*. It will be seen that an extraordinary amount of distortion results, and where the ampere turns or magnetising force due to the windings are such as to approach in magnitude the magnetising force of the polarising magnet, such a condition might easily arise. As an example, the case might be quoted of an average head receiver so connected to a valve circuit that the effect of the steady H.T. current opposes the polarising magnetism. When the H.T. current assists the polarisation, as it always should whenever the circuit is such that a steady current is allowed to

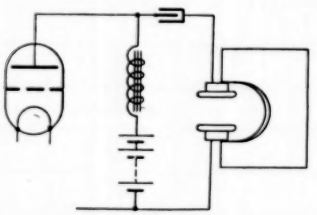


Fig. 3.—An arrangement to remove the steady component from the telephone circuit.

traverse the windings of a receiver, the conditions are, of course, quite different, and the diagram then takes the desired form, as shown in D, Fig. 1.

Having seen graphically the influence of the polarising magnets, it is interesting to note its importance numerically. Using H and *h* to denote the strength of the magnetic field in the air gap due respectively to the polarising magnet and the peak of the speech current, we have the change in the force of attraction equals $(H+h)^2-(H-h)^2$. This is because the attraction between a magnet and its armature is proportional to the square of the intensity of the magnetic field in the space between. The above expression simplifies to $4Hh$, which shows in a marked manner the importance of having a high degree of polarisation. It is interesting to note that without polarisation the expression becomes, not $4Hh$, but simply h^2, and when *h* is small, the effect being proportional to its square must be very small indeed. Usually, of course, H is very large compared with *h*, often several hundred times, and thus $4Hh$ becomes a formidable amount.

Reasoning in the foregoing manner, it would appear desirable to increase H as much as possible, but unfortunately other factors enter into the problem. Fig. 2 is a typical permeability curve for soft iron. From this it will be seen that the permeability varies very considerably according to the intensity of the magnetising force. At very low values the permeability is low, also at high values the permeability falls off in a marked manner. This fact is likely to have an appreciable influence on the action of a receiver, and should be studied in some detail. Considering the magnetic circuit of a receiver we have three main components: magnets, air-gap and armature or diaphragm. The first is a doubtful quantity, as it is usually composed partly of steel and partly of soft iron. The extent to which the steel portion enters into any rapid flux changes depends upon the design of the receiver, and, to avoid going too deeply into detail, it is proposed to ignore the steel, and assume the magnetic circuit to contain only iron and air-gaps, the latter including the leakage flux in the return circuit. Of this circuit the diaphragm is the portion most likely to become saturated, and, therefore, its permeability will be lowered with increasing polarisation. As a result, it will be less susceptible to any slight change in strength for the speech or signal current. The importance of this loss of susceptibility will depend upon the relation and proportion of iron to air-gap in the particular design under consideration. This then brings us to the study of the effect of the air-gap on the sensitivity of the receiver.

Many receivers are arranged with a mechanism whereby the air-gap may be adjusted whilst the receiver is in use. If receivers were always used without any direct current flowing, such means of adjustment would be unnecessary if the receiver was correctly proportioned in design. Where D.C. does flow, it is often possible to effect an improvement in reception by adjusting the air-gap in this manner. Reducing the effective length of the air-gap will, of course, reduce the reluctance of the magnet circuit. This will give rise to a greater total flux for a given magnetising force or ampere turns, and

together with the effect of the "square" laws, previously mentioned, will result in a very considerable increase in pull on the armature. Here the mechanical aspect of the subject arises, and it is not unreasonable to expect that there is a definite minimum air-gap for a diaphragm having a definite diameter, thickness and elastic properties. One can imagine a receiver with weak polarising magnets having the air-gap reduced almost to the point at which the diaphragm will lock. In the extreme, this cannot be fully efficient, and thus we see that to secure maximum efficiency it is desirable to have the intensity of polarisation under control. In the case of receivers tuned for sensitivity, therefore, both the air-gap and the magnetisation should be under control.

If it were possible to provide steel magnets of ample strength, a piece of iron arranged as a magnet shunt would give the desired means of adjustment. Another and perhaps better plan would be to use an electro-magnet for polarising the receiver in place of the usual steel magnet. Adjustment of the current in this would then give complete control. Both the above-mentioned methods necessitate the construction of special receivers, but by exercising a little ingenuity the intensity of polarisation of ordinary receivers could be controlled within reasonable limits. If this is to be attempted it is advisable first to

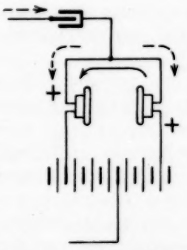


Fig. 4.—Showing how a local magnetising current may be provided.

arrange the receivers so that they may be independent of the steady plate current as supplied to the last valve. The usual manner in which this is accomplished is shown in Fig. 3. A transformer could be used, but it is probable that the choke method would have a higher efficiency and, moreover, greater freedom from distortion. Generally, no great importance is attached to the valves of the choke and condenser used in this circuit, except to specify a choke having an inductance of, say, 2 henries, and a condenser of about 0·25 mfd. The writer would venture to suggest that in such a circuit the value of the capacity of the condenser is of considerable importance. Seeing this condenser is in series with the receiver, the impedance of

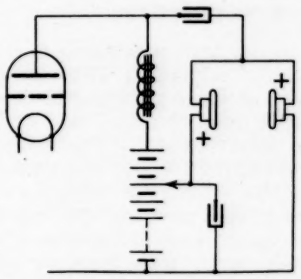


Fig. 5.—The magnetising current is provided by the high tension battery.

the circuit as a whole, to current at speech frequencies, is materially affected, and by selecting a condenser of suitable value it should be possible to adjust the impedance of this output circuit to the value most suitable for the valve. In this way distortion could be avoided and the utmost efficiency secured. However, this is somewhat irrelevant at the moment, and we will assume the circuit to be as shown in Fig. 3. Now by connecting, as shown in Fig. 4, two receivers similar in design and magnetic properties, with their polarity correctly arranged, it is possible to pass a steady direct current of the desired value in the local circuit by adjusting the number of cells. This, then, gives a means of controlling the value of the total polarisation by adding or subtracting a small magnetising effect due to the local current. It will be noticed that with 10,000 turns on the receiver, a current of 3 ma. will give 30 ampere turns, and thus the variation available is quite considerable.

A convenient method of obtaining the same effect without using an additional battery is given in Fig. 5. The ordinary H.T. battery is used to supply the current, and a condenser is added to avoid the possibility of noise arising from the battery.

The Manufacture of High Resistances for Wireless Receiving Circuits.

Although the grid leak is the most usual application of high resistances for wireless purposes, non-inductive resistances are universally employed throughout wireless receiving and transmitting systems. Below will be found details of the manufacture of resistances capable of carrying considerable currents with a reasonable degree of constancy.

THE use of high resistances in receiving circuits originated with the popular type of valve rectification known as "cumulative grid rectification," or "leaky condenser rectification." This method consists of connecting the grid and filament of a valve to the supply of energy requiring rectification, and allowing the impulses to be stored up in a small condenser inserted next to the grid, thus lowering the grid potential. This would cause the grid to assume some large and indefinite negative potential, but is prevented from doing so by connecting a high-resistance leak across the condenser, which allows the charge to leak away and the grid to be brought back to zero potential ready for the next train of impulses. The value of this resistance should be of the order of a megohm, more or less, and is known as the "grid leak."

One of the first things used as a makeshift for these grid leaks was a few lines drawn with a pencil across paper, wood or some other convenient substance. Amongst many other devices pressed into service was blotting paper soaked in Indian ink, which is now the favourite "home-made" grid leak. All these have one disadvantage in common—they are all more or less "noisy" and variable, due to the fact that there is no absolutely continuous path for the current. The conducting material is carbon, and this is mixed with foreign substances, so that, in the case of Indian ink on paper, two minute pieces of carbon carrying current are placed next to one another on the paper, but are not quite touching; consequently, as current passes, it does so with a small spark—a number of these small sparks setting up microphonic noises.

It was with a view to absolute "silence" and constancy that S. R. Mullard evolved his patent "carbonised cellulose resistance." This is, in effect, a stick of pure carbon of suitable resistance, conveniently mounted in a small tube. Its manufacture will be described later.

Modern commercial resistances may be broadly classified under four headings:—

(*a*) Graphite.
(*b*) Colloidal carbon.
(*c*) Solid carbon.
(*d*) Metal.

Under (*a*) may be grouped the original pencil lines on wood and the many forms of compressed graphite mixture which are to be found on the market to-day. It may be mentioned in passing that the writer has recently tested some graphite resistances originating from Germany. These seem to be extremely sensitive to voltage—a resistance marked 2 megohm at 110 volts would vary between 2 megohms at 250 volts up to about 80 megohms at 7 volts. Of course, they were quite unsuitable for use as grid leaks.

Under (*b*) are grouped those resistances which consist of cardboard, blotting paper, etc., soaked in Indian ink.

The disadvantages of resistances falling into these two groups have been pointed out previously—they are microphonic and some of them very unreliable, because in no case is there a continuous path through the resistance.

To group (*c*) belongs the carbonised cellulose resistance of Mullard. This is made from a bundle of cotton fibres, which is first of all parchmentised in order to hold it well together and make it rigid, after which it is carbonised and takes the form of a fibrous carbon stick, like a stranded cable. These resistances are proportional to length; they have perfectly even conductivity, and hence are perfectly "silent."

In the last group (*d*) is the spluttered metal type of resistance. This consists of some sort of glass tube on the walls of which platinum is spluttered by means of an induction coil. The result is, in appearance, like partially smoked glass.

It makes an excellent resistance, and, when properly prepared, should be quite silent; it will also take a comparatively large current, and shows no tendency to over-heat.

i.e., it must dissipate 13·8 milliwatts; also the high tension must be increased by 32 volts to allow for the drop in resistance.

In considering the suitability of the various types of resistance for anode resistances, the same remarks apply as for grid leaks, but, in addition, the fibrous carbon is capable of withstanding a much greater current than any of the other types, with the exception of the spluttered platinum. Also the shape and size of the resistance now becomes of

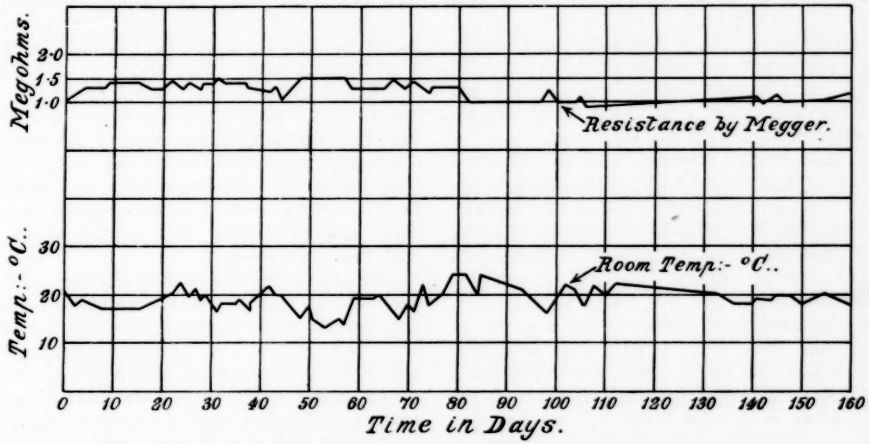


Fig. 1—Showing the resistance of the carbonised cellulose variety measured at intervals under different temperature conditions.

The great advantage held by this type over carbon resistances generally is that it possesses a low positive temperature coefficient, whereas that of the carbon types is high and negative.

The advantages are, unfortunately, outweighed by the disadvantages which are: (1) High cost; (2) easily broken; (3) the platinum tends to flake off the glass, thus causing the resistance to increase with age.

Another use for resistances is in the anode circuit of resistance—capacity coupled valves. The values of these "anode resistances" are usually from 50,000 to 100,000 ohms, and they are required to carry more current and to withstand a higher voltage than grid leaks. The average working anode current of a small receiving valve is about 0·4 milliamps.—supposing an 80,000-ohm resistance to be used, this must carry 0·4 milliamps. and the voltage drop across it will be 32 volts, some importance. Where a resistance capacity coupling is used the amplification obtained depends upon voltage drop across the resistance, which is communicated to the grid of the next valve: supposing the resistance to have self capacity, such as a wire resistance would have, this self capacity will act as a by-pass and reduce the effectiveness of the resistance. For example, let the resistance be 100,000 ohms and its self capacity be 5 micro-microfarads, then the self capacity would, at 1,000 metres wavelength, carry as large a current as the resistance, thus halving its effectiveness. Self capacity in a resistance is equally disastrous when shunting high-frequency transformers by resistances.

The value of an anode resistance depends mostly upon the type of valve with which it is used—some people prefer the value to be twice that of the impedance of the anode

path, but this is generally not known, and the characteristic curve of the valve is not always available. For general purposes it will be found that a resistance of 70,000 or 80,000 ohms will give good results either as an anode resistance or as a high or low-frequency transformer shunt. It must be remembered however that, when using a resistance in the anode circuit of a valve, more high tension should be used to compensate for the voltage drop in the resistance.

The type of resistance used in high frequency circuits should be of a design giving the least self-capacity, and, in practice, a resistance rod ¼ in. in diameter and about 1½ ins. in length is found sufficient. Inside this is a fibrous carbon rod 3-32nd in. diameter and about 1 in. long, held axially and filled round with paraffin wax.

As has been already stated, Mullard resistances are made from carbonised cellulose. The raw material is cotton in the form of a rope having about 250 strands forming a loose bundle about 5-16ths in. in diameter. This is passed slowly through a bath of sulphuric acid, where it is partially digested. From the acid it is drawn on to a drum in water, and has now a stiff and jelly-like appearance, *i.e.*, it becomes parchmentised. It is then thoroughly washed to remove superfluous acid, and hung up on a screen to dry. Weights are tied to each end in order to stretch it. When thoroughly dry the parchmentised cotton has shrunken considerably in diameter and has become stiff and tough—welded together, so to speak. It is then cut up into suitable lengths.

A section through one of these "waxed threads," as they are called, reveals a number of wax-like strands—in fact, similar to the cross-section of a stranded cable.

The threads are then carbonised by packing with graphite in metal cylinders and roasting in an electric furnace. This results in a stiff piece of carbon having a resistance proportional to length—the overall resistance varying according to requirements. For a 2-megohm resistance the threads would be furnaced so as to give carbons having a resistance of about 2 megohms for a 1-in. length.

A section taken through the carbon and magnified would show a great number of carbon threads welded together. A current traversing the section would have open to it innumerable parallel paths through the threads. This ensures a perfectly even and unobstructed flow of current, and is the secret of the perfectly silent working of these resistances.

The carbons from the furnace, having been broken up into inch lengths, are then measured and sorted out into their different values. Next, wires are wound round the ends of the carbons and pasted with special paste to ensure a perfect contact between wire and carbon. The paste is dried and the wired carbons are passed on to another instrument, where they are re-sorted and the values immediately required are put into tubes and passed on to be assembled. The resistances are then soldered to one end cap, the tube filled with the best-quality paraffin wax, and the other end cap is fitted and soldered.

The assembled resistances are then cleaned and sent to another instrument, where they are sorted out according to their values and then sent to the labeller. Having been labelled, the resistances are again tested for value and length to ensure that they are correctly labelled and to specification.

It is usually of interest to know what tests such commercial articles are required to pass. All Mullard resistances are tested with 250-volt meggers; this ensures that they will stand up to ordinary working voltages, which, as a rule, are negligible in the case of grid leaks, and seldom greater than 100 for anode resistance. They are made to within 20 per cent. of their nominal value, as shown by the label, and these limits are rigidly adhered to. All resistances undergo four megger tests during the process of manufacture, particular care being taken to discard any completed resistance or carbon which shows any sign of abnormality in current-carrying capacity, etc.

These resistances keep their values permanently, and are practically indestructible unless very badly treated. A typical life curve is given showing daily tests at 250 volts over a period of about six months.

The Reflex.

So much literature has recently appeared relating to dual amplification circuits, that we are giving below a summary of the development of reflex work, together with practical data, so as to enable the experimenter to grasp the position.

THE present "boom" in reflex circuits is a good example of the way in which original work is overlooked, in view of the fact that such circuits have been quite well known for many years.

To be precise, we find among the patents now owned by the Marconi Company, No. 8821 of 1913, granted to W. P. Thompson, communicated by the Ges. fur Drahtlose Telegraphie, of Berlin, which covers a typical reflex circuit. A very similar circuit was developed by Captain Round in 1915 for use with the Round Valve, and was extraordinarily efficient. It will be remembered that this valve had a very high μ, and the results with the—as it was then called—"Dual Amplification" circuit and the carborundum detector were fully equal to a normal three-valve circuit of the present day.

At about the same time Marius Latour was doing excellent work on similar lines, and during the years 1918-1922 much work was done and published by Grimes in America and Voigt in England. There was also much experimental work by others who have not published their results.

It is taken for granted that all readers of EXPERIMENTAL WIRELESS know already the main idea of reflex working. But those who have not yet tried out such circuits appear to ask such questions as the following:

(1) What will a reflex do as to power, compared with straight circuits on the one hand and "super" circuits on the other?

(2) What about distortion?

(3) Is a reflex reasonably easy to handle?

(4) What are the important points of design?

We will try and answer these queries,

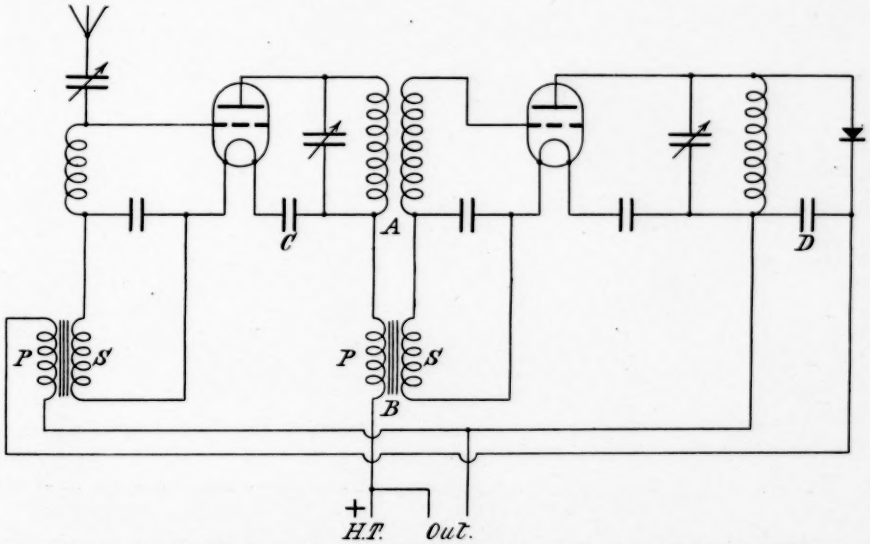


Fig. 1.—The simplest reflex, the direct, in which both H.F. and L.F. go through the valves from left to right.

basing our statements on a personal experience from 1915 onwards.

(1) As to power, one can best state it by comparison with another set of the same number of amplifying stages—remembering that the detector valve in a normal set is often counted (wrongly, we think) as a "stage." Thus a three-valve straight set has two amplifiers and a valve detector. If it is of the popular 1 H.F.—1 L.F. type, it is directly comparable with a one-valve reflex with valve detector; and the reflex will probably give about 10 per cent. less power—using, of course, only two valves to do it.

As to comparison with super-regenerative sets, we do not like to speak too positively. Our own experience is that on 300-400 metres a two-valve reflex gives practically the same power as a two-valve Armstrong, much better tone and easier handling. But we have done much more work with the reflex than the Armstrong, and possibly a super-regenerative expert might get better results with the latter type.

(2) Our experience as to distortion is that the reflex differs in no way from a *similar* straight set. We say "similar," for an important point is involved. The reflex does

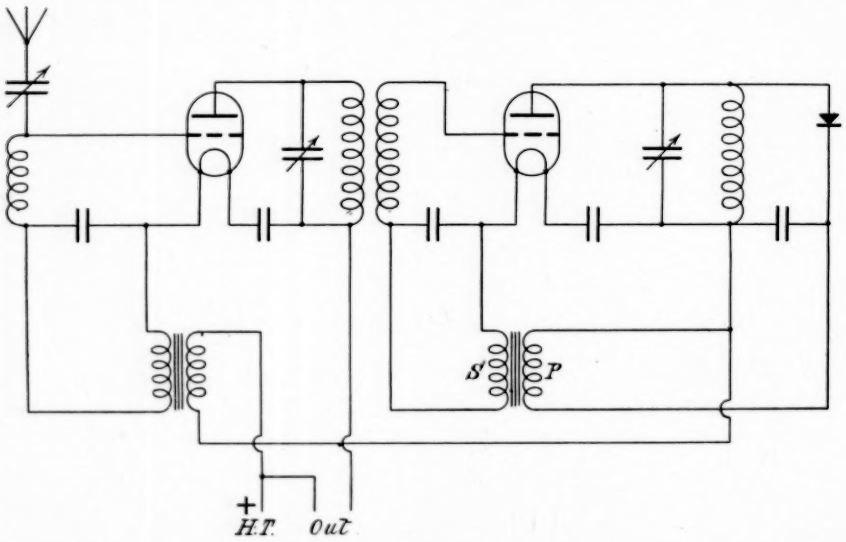


Fig. 2.—In the inverse system, the H.F. goes from left to right, while the valves are used in reverse order for L.F. amplification.

A notable point about the reflex is that the detector valve, if used, cannot be made to "doubly magnify"—at least, not to the writer's satisfaction. The type lends itself particularly well to crystal rectification. This has real advantages, as will be explained later. Generally speaking, a one-valve reflex with crystal detector has a power between a two and a three-valve straight set; a two-valve reflex with crystal comes between a four and a five-valve normal set. The three-valve reflex, *if skilfully designed*, is better than a six-valve normal, but it is not an easy set to design or handle.

not lend itself to tuned anode H.F. coupling. As a rule, one has transformer coupling and no grid condenser and leak. Now, grid rectification is notoriously a source of distortion, unless special precautions are taken; hence a reflex gives a much better tone than the average valve set. If, however, a straight set is designed carefully to avoid this difficulty on the H.F. side, and uses anode rectification, there is nothing to choose; and if resistance coupling is used for the L.F. on the straight set, and transformers for the reflex, the straight set will probably be the better.

In other words, purity is a matter of

design in either case. If both sets are carelessly designed, the reflex is likely to be the better.

(3) This point, ease of handling, is again a matter of design. The reflex having as many H.F. stages as L.F. tempts one to work for selectivity. For example, in the author's favourite two-valve set there is a tuned aerial circuit, a tuned intervalve circuit, and tuned valve to crystal circuit ; and reaction is used across the second valve. Naturally, the set is very selective, and accurate tuning is needed. But this is not by any means a necessity. The selectivity may be reduced, and reaction done away with.

It is, however, found important to include grid bias among the adjustments, although it is not used frequently.

With regard to stability, an ordinary reflex is very much on a par with any other set containing several H.F. stages. This matter will be further dealt with later when discussing inverse and direct reflex circuits. On a full-sized aerial a two-valve reflex is a perfectly stable set, not even requiring skill.

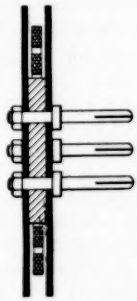


Fig. 3.

Fig. 4.

Fig. 3.—A successful design of H.F. transformer for plugging in. It has a low inter-winding capacity.
Fig. 4.—In a radio choke, the overall size must be kept small to avoid self-capacity.

On a frame or small indoor aerial care must be used to prevent the first valve oscillating. As will be seen from the diagrams reproduced in these pages, the crystal detector comes across the anode coil of the second valve, and its damping action stabilises this admirably.

A three-valve reflex is always likely to be a tricky set. It comprises three stages of L.F. amplification. This means that a fairly powerful valve must be used for the last stage—say, an L.S.5, or its equivalent. But this valve is also doing H.F. work, and it may not be really well suited to this purpose. Further, the amplification is so high that any error in design or construction is likely to result in instability or noisiness. In actual practice a two-valve reflex is of ample strength for any ordinary work. If particularly powerful loud-speaker results are required it is simplest to add one stage of separate power amplification (L.F. only).

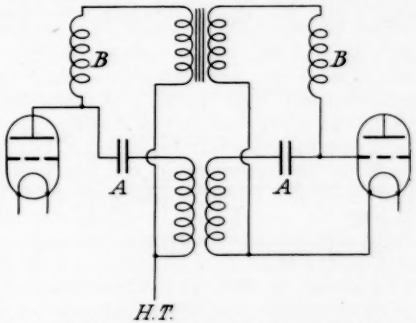


Fig. 5.—An alternative arrangement for the coupling, in which H.F. and L.F. are in parallel.

One point as to which there is misconception is the reliability of the crystal. Naturally if one uses galena, requiring a delicate contact and set in a badly-designed detector, there will be trouble. But by using a well-made detector with arrangements for steadying the point, or by using a molybdenite or perikon detector, the difficulty is made non-existent. The author's two detectors are adjusted on the average about once in three weeks, and then usually only in an effort to achieve perfection—not because they are really off.

(4) Now as to design. It must be realised that the design of any set—reflex or other—is a large job if it is to be done properly. One or two points about the reflex need special consideration. Firstly, the right valves and their adjustments. The designer must never forget that for the same strength of audio output the valves are doing more work in a reflex. Take, for example, a one-valve circuit. If the input has an amplitude which we will call A, then the H.F. output for the crystal (using an ordinary valve with $\mu=6$) will be about 4A. This will be converted by the crystal circuit to an L.F. output of smaller amplitude, say A again, which is amplified

by the L.F. transformer (as regards voltage) to perhaps 2A, and delivered to the phones after a final amplification to, say, 10A. So that the valve has a total input of 3A (H.F.+L.F.) for an output of 10A. If it were the last valve of a three-valve set with an output of 10A, it would have an input of 2A only. In other words, the valve to be used in a reflex must be able to deal with a larger input for the same audio-frequency output. An approximate estimate of the increase can always be made quite easily as above.

Another important point of design, in a set comprising more than one amplifying valve, is whether to use a direct or inverse circuit. The difference is shown clearly by comparison of Figs. 1 and 2, which show the two types simplified by the omission of batteries, etc. There are points to be made in favour of each type, but the author is firmly convinced that for normal conditions, especially if long wave work is to be catered for, the direct is superior. None the less, the inverse has important advantages, so that the point merits discussion.

A claim frequently made for the inverse is its great advantage in equalising the load on the two valves, the largest H.F. input going to the valve carrying the smallest L.F. But this does not always work out in practice. In the case of a two-valve set with crystal detector, we are likely to have the following inputs: 1st H.F. 1; 2nd H.F. 4; 1st L.F. 1; 2nd L.F. 10. In a direct set the first valve will have a total of 2, and the second a total of 14; in an inverse the inputs will be 11 and 5.

But in a three-valve set with valve detector the inverse is even further from equal input to the various valves, thus:

Valve No. ..	1	2	3
H.F. Input ..	1	4	16
L.F. Input ..	1,600	160	16
Total	1,601	164	32

If a direct circuit were used the third valve would carry 1,600+16=1,616 units of input, so that the valve used need only be of

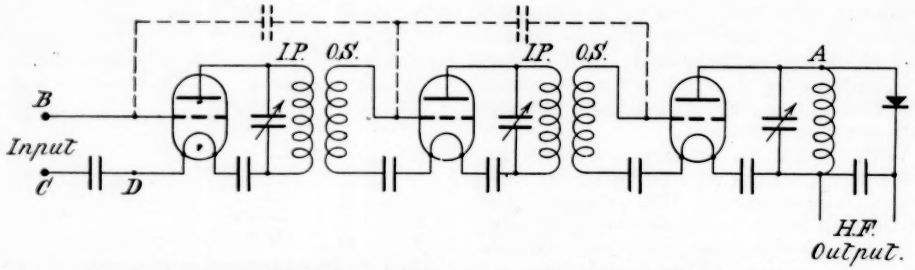


Fig. 6.—The H.F. circuits of a three-valve set—the idea can obviously be extended to any number.

1 per cent. greater capacity than the first in the inverse—a quite unimportant difference.

A really important point is in perfect separation of H.F. and L.F. currents. Taking, for example, the intervalve circuits of Fig. 1, in theory the H.F. current is transferred *via* A, and the L.F. *via* B. But in practice there will be a certain transfer of L.F. energy *via* A, and owing to the self and mutual capacity of the windings of B, and the fact that the by-pass condenser C is not infinitely large, there is also a transfer of H.F. energy *via* B. Now in this particular case it does not matter—either transformer transfers energy from the first to the second valve. When, however, we come to consider the intervalve circuit of the inverse, we find that H.F. energy from the anode may leak back to the grid *via* the L.F. transformer, while L.F. energy, which is intended to be transferred towards the left in the figure, may leak back towards the right *via* the H.F. transformer.

When the H.F. and the L.F. frequencies are of the order of 1,000 and 1,000,000, as in the case of short-wave work, this leakage is not serious; but for longer waves it rapidly becomes important; so much so that at 15,000 metres (N. equals 20,000)

an inverse set is prone to oscillate continuously.

A possible way to avoid this is by substituting for the by-pass condensers a set of properly designed filters. But this means quite a complicated set. Should this trouble occur on a direct set it can be overcome by a single filter at the point B to prevent H.F. leaking back to the first valve, while in the inverse each anode circuit needs a filter.

On the other hand, the inverse has a real advantage where there is likely to be audio-frequency interference—tram lines near the aerial, etc. In the direct set any such L.F. interference passes through the set and is considerably magnified. In the inverse, on the other hand, it only passes through one L.F. stage, and is, therefore, not so troublesome. The only way of avoiding this difficulty, if it is serious in the direct system, is to use No. 1 valve as H.F. only.

Perhaps the next important point to consider is the type of intervalve coupling to be used. In his own practice the author has standardised simple transformers as shown in Figs. 1 and 2. The L.F. transformers are of normal type, carefully chosen. Since Some of the cheap transformers now available have performed excellently.

With regard to the H.F. transformers, the design found most successful has close coupled windings of 1 to 1 ratio, either winding being shunted by a tuning condenser. As an example, the range from broadcast band up to 600 metres is well covered by windings of 50 turns each, internal diameter one and half inches, shunted by a ·0005 μF. variable. Windings of 2,100 turns each cover the highest wave-length used. It has been found advantageous to design the transformer so that the interwinding capacity is low. A satisfactory type is that shown in Fig. 3, in which it will be seen that the windings are edge on to one another. They are separated by twenty turns or so of cotton thread.

If selectivity is not specially desired, there are distinct possibilities in resistance coupling. The one difficulty is to find a satisfactory value for the grid condensers. These have to be large enough to pass L.F. currents fairly freely, but if they are too large, there may be trouble owing to the large time constant of such a condenser with the necessary resist-

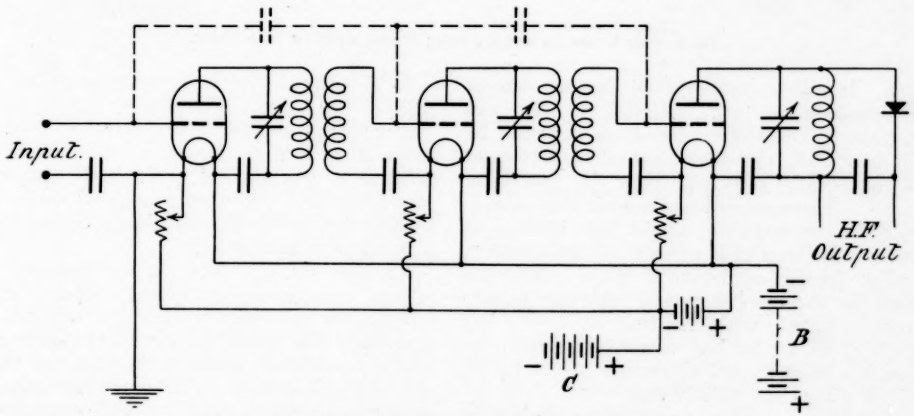


Fig. 7.—The set of Fig. 6, with the filament circuit and batteries added.

their windings are all shunted by condensers it is desirable to choose a make having naturally a low self-capacity, as otherwise the addition of the outside condensers may give a muffled tone owing to partial shunting of the high harmonics. There is, however, no serious trouble in getting suitable types.

ance. For example, a suitable value for L.F. resistance coupling is ·1 μF. But this with a 1 MO. grid-leak gives a time constant of ·1 sec., which means that any accumulated charge would paralyse the valve from the H.F. point of view. This difficulty may be avoided by preventing any such accumula-

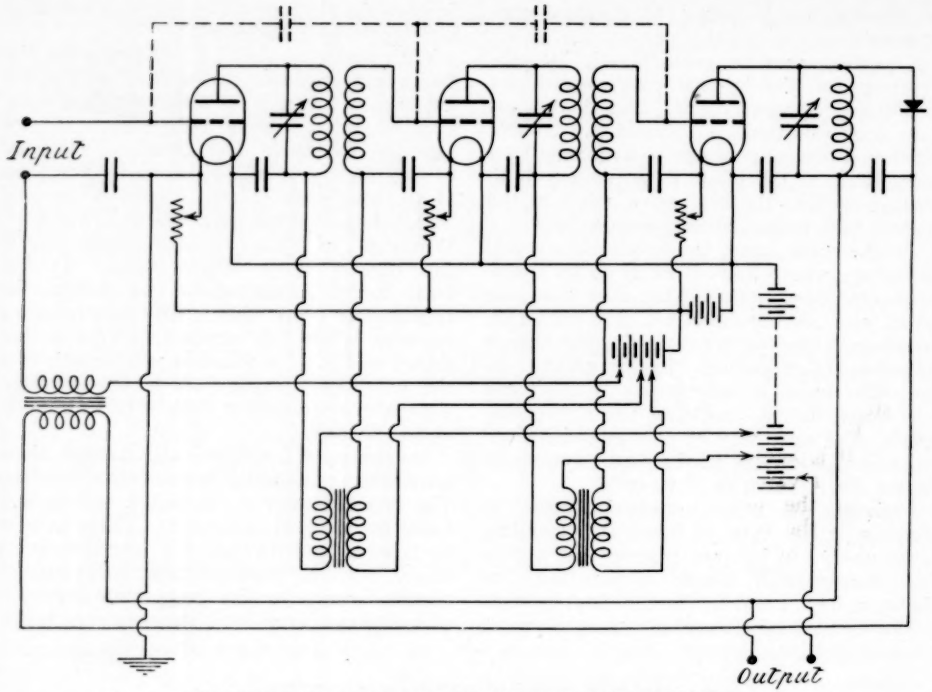


Fig. 8.—Here is seen the complete wiring scheme, except for aerial tuning.

tion. It will be remembered that the valves in question are pure amplifiers. No grid current is, therefore, needed, as it would be for detection. The sole object of the condenser is to insulate the grid from the preceding plate. The lower end of the leak may, therefore, be connected to a grid bias battery of such value that grid current is non-existent, under which condition a large condenser may be used. The writer has not experimented largely with this type of circuit, but such tests as he has carried out seem to indicate that a grid condenser of ·01 to ·05 μF. is about the right value.

It is quite feasible to substitute chokes for the resistances, with a considerable saving in H.T. supply. The only difficulty is that a choke of sufficient value at audio frequencies will probably have too much self-capacity to be valuable at high frequencies. It is, therefore, usually necessary to use two chokes in series, the one nearer the anode being a radio choke of very low capacity, the other an iron core audio choke.

A suitable design for the radio choke is that of Fig. 4, which is about natural size. The windings should be of the order of 5,000 turns of 47 S.W.G., giving an inductance of 200,000 to 500,000 μH. with a self-capacity of 2 to 5 μμF. The audio choke would be of similar design to the secondary of an L.F. intervalve transformer.

Various circuits have been designed in which resistance or tuned anode H.F. coupling is combined with transformer L.F. coupling. The writer has not been able to get really successful results with these, so they are not reproduced. There is considerable field for experiment here for those interested.

Returning to the type most familiar, that of Figs. 1 and 2, in which transformers are used for both frequencies, the next question is the choice between series and parallel arrangements of the two couplings. The series arrangement has already been discussed; the parallel is shown in Fig. 5. L.F. currents are stopped off from the H.F. transformer by the condensers A, of the order

of ·0001 to ·001 μF., while H.F. currents are prevented from leaking through the self-capacity of the L.F. transformer by the radio chokes B, which (for broadcast and similar wave-lengths) might be of 5,000 μH. inductance, with a self-capacity not to exceed 2-5 μμF. A coil of the same type as Fig. 4, but with a coarser wire, giving, say, 300 turns in the space, would be suitable.

It is obvious that the two types of coupling may be intermingled in the same set ; one is in no way bound to adhere to one or the other. An advantage of the parallel method is that the stopping condensers, which (for L.F. purposes) are across the L.F. transformers, may be quite small, which may, with some transformers, give a better tone. On the other hand, any leakage past the H.F. choke has a serious effect on signal strength. Under normal circumstances, the author prefers the series method.

Two other points of general design. First, it will be found a great assistance towards stability and ease of operation if the set is earthed at some point on the filament circuit, and steps should be taken to ensure this ; second, if valves are to be switched in or out, it is useful to switch them out on the L.F., and leave them in as H.F. amplifiers, or *vice versa*, a matter which needs a little thought. These matters are taken up below.

It will, perhaps, be of assistance to carry the reader through some part of the design as a set, to show the method of approach. Naturally, the type chosen will be that which the author prefers for his own use. We will first lay out the H.F. circuits, of which the simplest possible theoretical design is that of Fig. 6. This practically speaks for itself. It will be noticed that the H.F. circuits are complete, though we shall obviously have to provide some D.C. connection from grids and anodes to filaments.

As has been already stated, the values of constants in the circuit are not critical. In order to save trouble in constant changing of plug-in transformers, the author uses fairly large tuning condensers (·0005 μF.). The transformers are of the type already described. The coil A may be a transformer if preferred, and is then interchangeable with the others. It may be placed so that it is coupled to either of the other transformers if reaction is desired. Neutrodyne condensers (shown dotted) may be added if desired, and are often valuable in steadying the set (the author's experience is that neutrodyne condensers are not, as a rule, very effective on *inverse* circuits).

The crystal circuit comes across the anode coil (or transformer secondary) of the last valve, and the resultant loading has an important effect. A low resistance crystal, passing a comparatively large current, flattens the tuning and stabilises the set. A high resistance type—or even more so, a valve detector—gives the opposite effect. It is found advantageous to use variable reaction by back coupling coil A, to compensate for differences in the crystal, which it does admirably. The transformers should be connected so that the ends most free from mutual capacity (normally I.P. and O.S.) go to grid and anode.

For long waves especially the ohmic resistance of coil A may mean that the steady anode current in it may cause a perceptible D.C. voltage across it, which naturally influences the crystal. A reversing switch is, therefore, useful, also a selector switch for two detectors.

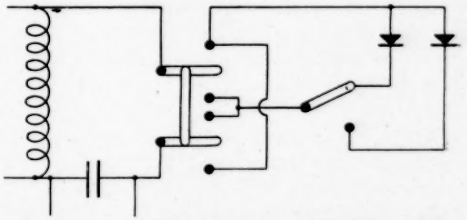


Fig. 9.—Further refinements are the use of a reversing switch and a selector for two detectors.

With regard to the "input" circuit, this may be of any kind, provided that there is a D.C. conducting path between terminals B and C. In view of the advantages of earthing the filaments, it is best to connect the earth of the set to the point D ; this throws the first by-pass condenser into the aerial circuit. As its capacity is large, its only effect from the H.F. point of view is a quite unimportant change in aerial tuning adjustments.

As to the size of the by-pass condensers, ·001 μF. is recommended for short waves, ·005 for very long. But except as regards purity of tone in telephony, their exact size is unimportant. For this particular purpose (telephony) it is a matter of suiting the condensers to the L.F. transformers.

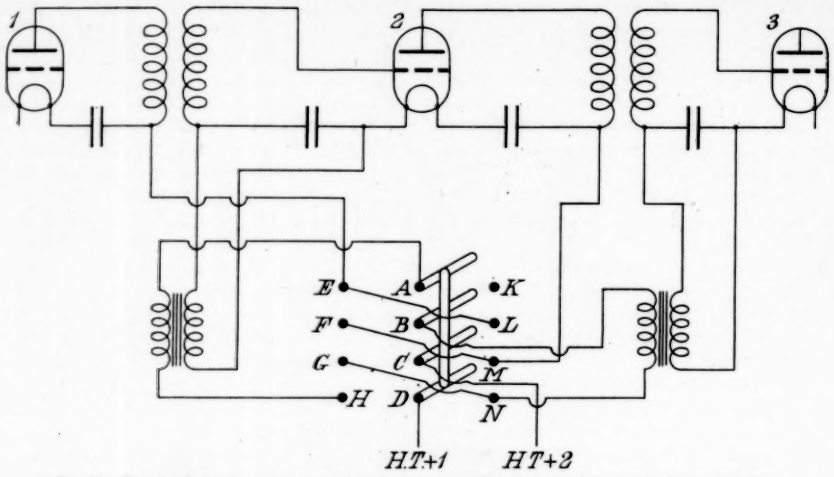


Fig. 10.—To cut out one stage, a four-arm switch must be used, so that the valve can still act for H.F. when cut out for L.F., and vice versa.

The next part of our design is the filament circuit, and this is shown, together with all the batteries, in Fig. 7. It is of the simplest nature. B is the H.T. battery, and C a grid battery. One master rheostat may be used, but is not considered good practice. The rheostats may be in the positive side, if preferred.

All that now remains is to complete the circuit by inserting the L.F. transformers, which gives the complete lay-out shown in Fig. 8. This looks at first sight rather formidable, but a closer inspection will show that it is not so in reality. It could have been made simpler in appearance by joining all the H.T. and grid bias leads, instead of showing separate tappings.

This lay-out shows no switchgear, which is better shown in separate details. Fig. 9, for example, shows the detector switches, of which one is a reverse, the other a selector. Fig. 10 shows the switch necessary to throw out one stage of amplification—in this case a L.F. stage. It will be seen that with the four-way two-throw switch to the left, the anode circuit of No. 1 valve is E.A.H.D., and that of No. 2, M.F.B.N.G.C., giving normal connections. With the switch over to the right the circuits are as follows: No. 1 valve anode E.L.B.N.D., passing through the second transformer primary; No. 2 anode, M.C., cutting all L.F. amplification out of this valve's province, while keeping it in service for H.F.

As will readily be realised, there is endless scope for modification in these circuits, without altering the main principle. It is thought that the suggestions already made will be sufficient to form a basis of experiment. As to the practical lay-out of the set, this also affords some problems. The author has refrained from suggestions in view of the widely different tastes of constructors. It is obviously important to get the H.F. transformers and the by-pass condensers near the valve sockets, with the object of getting short H.F. circuits.

It is obvious that much has to be left unsaid in an article, which can only cover the ground in a sketchy fashion. If the author has succeeded in attracting the attention of the amateur to a circuit of great possibilities he will rest content.

Transatlantic Radio-Telephony.

By Capt. ST. CLAIR-FINLAY, B.Sc.

Long distance telephony necessitates, amongst other things, a steady carrier and full distortionless modulation. How this may be obtained is described in the following article, which should be of great practical value.

WHILST much attention is being directed towards short-wave DX telegraphy, and remarkable results are being obtained in this direction by amateurs, comparatively little is now being done by them in the sister science of telephony, probably for the reason that, until the success of long-distance telegraphy on low powers has been fully established, experimenters are naturally more concerned in sheer "getting across" by the most promising means than in attempting more doubtful ones in the success of which they would feel less confidence, and the results already achieved afford ample vindication of this policy. In consequence, there are probably few stations now working DX on either side of the Atlantic specially equipped to do so on telephony, and it is possible that details of one so equipped may be of interest to experimenters in view of the future work that is certain to be done in this direction.

It is therefore proposed to give, not a general description of the station as such, but details of the special means adopted thereat to secure super-efficiency in the long-range transmission and reception of speech on low powers and short waves, together with a brief review of the main facts emerging from research work therein which it is hoped may be of interest; and it should be stated at once that these will refer, not to special directional and side-band systems now under investigation by the writer and others, but to the standard non-directional methods already in use by amateurs generally.

Clearly established by these experiments was the special importance of certain factors in the effective carrying-power of a modulated wave, and these, as far as possible in order of precedence, may be summed up as follows :—

Transmitter.

(1) Radiation efficiency of antenna.
(2) Modulated output to antenna.
(3) Purity of carrier.
(4) Quality of modulation.
(5) Sharpness of tuning and stability of wave.

Receiver.

(1) Reception efficiency of antenna.
(2) Sensitivity of receiver.
(3) Selectivity of tuner.
(4) Silent and distortionless amplification.
(5) General stability of circuits.

And it should here be remarked that, whilst these will be recognised by experienced radio-telephonists, and may be dismissed as entirely elementary by some, their supreme importance lies in the very fact that they *are* elementary essentials, and it was found that each and all required development to a point considerably beyond usual practice to make possible the results ultimately obtained.

First of all, since the actual results at the receiving end constitute our entire concern, our first consideration must be to get as much as possible into the *ether*, not merely into the aerial, and as this will very largely depend upon the efficiency of the aerial itself, which, in turn, will largely depend upon its suitability for the wave-length and power used, the first essentials must manifestly be scientific design and careful construction of the antenna system for the purpose in view.

Fortunately, the aerial dimensions allowed to amateurs under P.M.G. regulations are as suitable for work on 200 metres and under as they were unsuitable for the old 1,000-metre wave, and, though few amateurs may be able to work under anything like ideal conditions in other respects, their aerials can in most cases be made, in themselves at least, very nearly ideal for short-wave work, and the influence of this on the results obtainable is, of course, enormous.

Assuming, then, a really good and suitable antenna system, the next consideration of importance is the amount of *modulated* energy delivered to that system, and it

should be realised that it is of little use to produce a large aerial current unless a large proportion also of it is controlled—it is *control* that counts in telephony, not mere aerial current, and 1 ampere of which 80 per cent. is modulated will, for example, be more effective than 2 amperes of which only 35 per cent. is modulated. Therefore, the importance of having a modulator of sufficient power effectually to control our aerial current will be manifest.

At the same time, *quality* of modulation is of the greatest importance in long-distance telephony. Quite sufficient distortion may occur in transit due to atmospherical, topographical, geological and other conditions, as well as in the distant receiver itself when adjusted to the necessary sensitivity, to make the best of transmitted speech none too clear on arrival, and if distorted speech is transmitted in the first instance the result at the receiving end may be wholly unintelligible.

Neither can effectual depth of control be obtained without distortion unless a suitable control system is used, and unless the speech currents delivered to that system be themselves undistorted, and this demands :—

(1) A really good microphone—and it may here be remarked that the ordinary carbon instrument is by no means suitable for this purpose.

(2) A distortionless and silent amplifier—more than one stage coupled with such transformers as are generally available to amateurs is inadvisable, and it is preferable to use resistance or choke coupling.

(3) A pure and ripple-free carrier—smoothing of the H.T. supply requires special attention.

The importance of stability of the carrier itself lies in the obvious difficulty imposed at the receiving end of keeping circuits—probably several circuits—critically tuned to a transmission the wave-length of which is continually varying, and every precaution needs to be taken to guard against unsteadiness or " swing " of the carrier either during or between transmissions—the same, of course, applying at the receiving end and being included under the heading " stability of circuits," this matter being responsible for many of the symptoms commonly designated " fading effects." The last item, *viz.*, sharp tuning of the modulated output, is a matter of efficient transmission, *i.e.*, utmost concentration of the available energy into a definite operating wave-band of least possible width so as to ensure a minimum of diffusion loss, and lies in the correct design of the antenna system for the wave-length used and power handled, correct adjustment and tuning thereto of the transmitter, and the use of oscillation and control systems such as to ensure minimum possible " spreading " of the carrier due to modulation, about each of which much could be said that space unfortunately does not permit of here, the same applying to the effects of actual *wave-length*, which of course is a wide and far-reaching subject.

Finally, it should not be lost sight of that the receiver is just as important as the transmitter—the range and abilities of the one determine those of the other—and it is thought that the special importance of the considerations enumerated under that heading will be realised and understood by readers of this journal without further explanation.

Having now summarised, if perforce very inadequately, the principal lessons emerging from an investigation of the subject, we may now turn to details of the practical means adopted to meet them at the writer's station and a consideration of the actual results achieved thereby.

It being desired, for reasons which the experiments had demonstrated, to operate at the natural wave-length of the aerial, and it being also desired, since DX was the objective, to work on a wave-length clear of the fading-band, a working wave of the order of 150–160 metres was decided upon, and the first consideration was the arrangement of the best possible antenna system for the purpose.

Many different types, sizes and combinations of aerial and lower capacity were tried out, and that giving best all-round results was one of T form, which, however, could not be so conveniently arranged for permanent use as another one of the inverted L type which was practically as good, so this latter, details and diagram of which are given in Fig. 1, was that finally adopted :—

AERIAL.

Type.—Flat-topped, open-ended, inverted L.

Conductors.—Three, .25 in. enamelled copper ribbon.

Spacing.—6 ft.

Spread.—12 ft.

Length of Top.—55 ft.

Down Leads.—45 ft., three-lead convergent.

Height Overall.—55 ft.

Height above Counterpoise.—45 ft.

50 ft. and 42 ft. respectively, allowing 5 ft. maximum sag in aerial and 2 ft. in counterpoise.

COUNTERPOISE.

Type.—Open-ended, flat semi-fan.

Conductors.—Five, ·25 in. enamelled copper ribbon.

Spacing.—6 ft.

Spread.—24 ft.

Length Overall.—100 ft.

In Leads.—Five, convergent.

Height above Ground.—10 ft. (8 ft. at centre, allowing 2 ft. maximum sag).

EARTH.

Three conductors of $\frac{3}{8}$-in. silicon-bronze strip, length 100 ft., spacing 12 ft., spread 24 ft., buried 1 ft., immediately below counterpoise.

ANTENNA CONSTANTS.

h=12·8 m. $R\gamma$=10·0 ohms.

c=·00035 mfd. λ=160 m.

Rdg=2·8 ohms.

A larger and taller aerial could quite conveniently have been erected, but this would have brought the fundamental higher than would have been desirable, whilst that described gave most excellent results, and proved scarcely open to improvement for the purpose intended, viz., tran mission and reception between 100 and 200 metres.

All conductors in aerial and counterpoise are drawn as taut as possible to prevent sway, and are arranged symmetrically and of exactly equal length from lead-in to free end, which was found an important point, whilst insulation throughout the system is very carefully carried out and is proof against all weather conditions and many times the power likely to be used—also an important point.

Insulators of the De-la-Rue ribbed and Buller porcelain type are used, nowhere less than two in series, whilst the leads-in are also of the heavy ribbed type mounted centrally in 15-in. glass plates and protected by drip-cowls, the minimum leakage path throughout the system being 30 ins. Equal care is taken regarding capacity effects, as may be judged from the small capacitance figure of ·00035 mfd. for an antenna of these dimensions; ohmic resistance is reduced to a minimum by the use of enamelled ribbon of high conductivity, which is unbroken and continuous from lead-in to the free end of each conductor, thus eliminating joints; inductive, absorptive and other undesirable effects are minimised by such spacing of the masts, guys, etc., as to ensure absence from the aerial field of foreign masses or conductors nearer than the counterpoise itself, by mounting the latter on posts well outside its own field, and by insulating and breaking up all guy-wires, etc., into three unequal

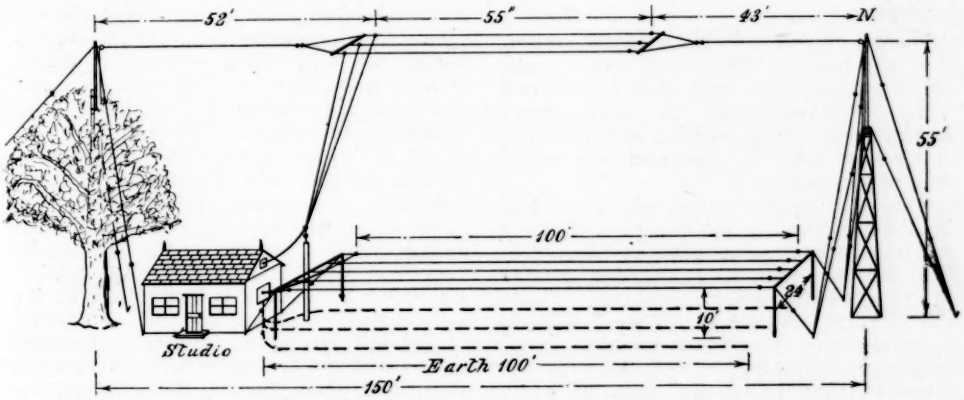


Fig. 1.—Showing general arrangement of the aerial, counterpoise, and earth system.

sections—no rope of any kind being used; and the total losses in the system are consequently very small, R*d* and R*g* together amounting to the low figure of 2·8 ohms, whilst the effective height is proportionately good, the radiation-resistance of 10 ohms being probably exceptional for an amateur antenna.

It is here worthy of note that the total cost of this system—which, whilst admittedly good, may be regarded by some as unnecessarily elaborate—amounted to £10 10s. inclusive of masts, which, considering its supreme importance, is regarded by the writer as a distinctly small and well-justified proportion of the total cost of one's apparatus.

Having now a suitable antenna system, the next item of importance was a really efficient transmitter, and, after experiments with various oscillators, the circuit shown in Fig. 2 was finally adopted and a suitable transmitter built for 100 and 200 metres and 10–100 watts.

This is a peculiar circuit which can best be described as a loose-coupled Colpitts, and is a result of various attempts to combine high efficiency with dead-steadiness of wave in a practical low-power transmitter. Unlike the Colpitts, transfer of energy is entirely independent of the aerial inductance, as the necessary inductance is provided in the transfer-circuit L2-C2, the value of which can be adjusted to the ideal, and any swinging or variation of the antenna constants is without effect upon the transmitter oscillatory circuits, or, therefore, upon the wave-length radiated, although tuning is exceedingly sharp. The circuit is particularly suitable for work about the fundamental, as the degree of coupling required is small, and, operated at the fundamental (160 metres), it is found that five turns each on A.T.I. and coupler suffice for full transfer of energy with suitable inductances, it being possible to work quite close to the natural wave-length of the aerial without necessity for a series condenser if so desired.

In addition to these special advantages, the circuit is highly efficient, input-to-output efficiencies exceeding 80 per cent. being obtainable with a single valve, rising as high as 85 per cent. with two valves in parallel if properly adjusted, operation being at the same time quite stable and adjustments not too critical. The extreme tuning range is 100 to 200 metres.

With regard to actual details of this transmitter, the A.T.I. and coupler are exactly similar coils of the flat spiral type, each 8 ins. square, and consisting of six turns of ¼ in. by 18 gauge stiff copper strip, air-spaced ¼ in. between turns, both mounted together ½ in. apart in a skeleton frame, the coupling being fixed. Aerial tuning is accomplished by a ·001 mfd. series condenser, a similar condenser below the A.T.I. providing the tuned-earth, whilst a third of similar value fine tunes the transfer-circuit. The C.C.I. consists of 22 turns of 16 S.W.G. bright copper wire, air-spaced 3-16ths in. on a skeleton rectangular frame 6 ins. square, with selector-clip, the anode-tap taking the form of a variometer wound with 18 D.C.C. wire, 20 turns each on stator and rotor, these being of 6 ins. and 3½ ins. diameter respectively. The H.F. choke W in the H.T. lead, which also functions as a wavemeter, the tube P ionising when in resonance, is a similar variometer with 52 turns of 20 D.C.C., and a calibrated dial giving direct λ readings. The grid choke is wound with 100 turns of 40 S.W.G. Eureka on a 2-in. former, and a third choke, L7, designed to ensure complete separation of the H.F. and D.C. circuits, is similarly wound with 75 turns of 16 S.W.G. enamelled wire on a 3½-in. former, across which the L.T. voltage drop is negligible up to several amperes. All coils are mounted on porcelain insulators and set well clear of the panel and controls for avoidance of capacity effects, whilst the short aerial and counterpoise leads within the operating room are also kept well clear and are suspended from the roof on porcelain insulators, the leads themselves being of heavy rubber-sheathed high-tension cable.

The calibrated twin-reading 0–2–4-amp. aerial ammeter, having an appreciable resistance when that of the aerial circuit itself is so low, is inductively coupled to the earth lead, whilst the 0–4–8-amp. transfer circuit meter, having a negligible resistance, is connected directly in series with that circuit, the indications of these two meters, which have 5-in. dials readable at a distance, greatly facilitating the accurate resonation and adjustment of the circuits. The pilot lamp P is connected across the H.F. choke,

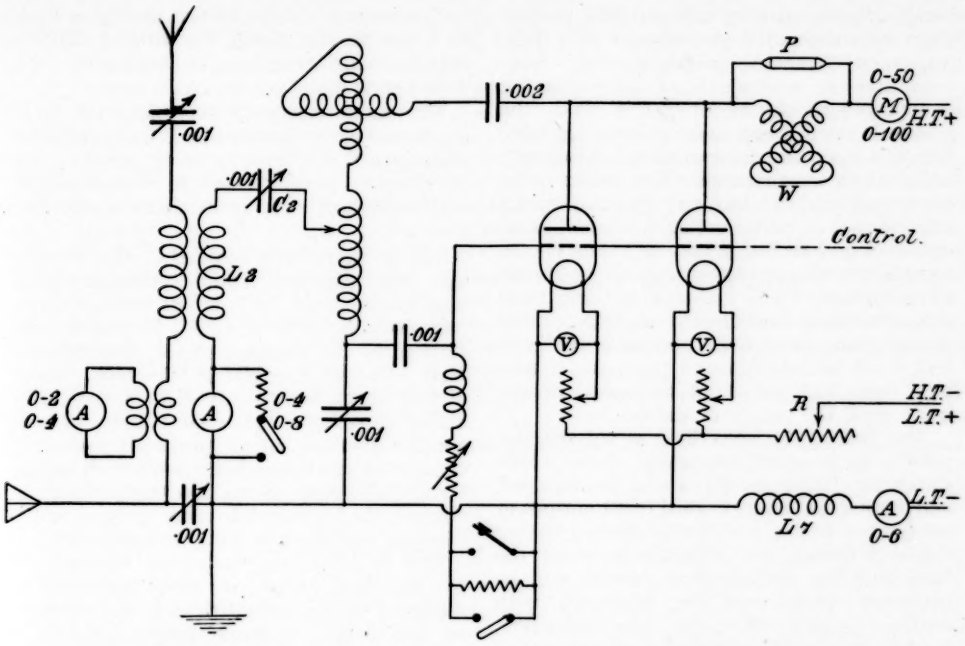


Fig. 2.—The peculiar oscillator embodying several features to meet the special requirements of the transmission.

and this lamp—which consists of a small cylindrical neon tube evacuated to a pressure of 1 cm. of mercury with a small external electrode at either end—whilst absorbing a negligible amount of H.F. current, is brightly ionised thereby, and, owing to the complete absence of inertia, affords sensitive visual indication of the modulation control not readily obtainable by other means, an electro-static indicator of this kind being of special value when the control is exercised equally by increment and decrement, as should be the case in a choke-controlled transmitter. The method of combining the functions of pilot, H.F. choke and wavemeter, enabling the setting of the transmitter to be instantly determined, is original, and may be of interest.

For telegraphy the method of keying may be noted, as this is simple and gives excellent results. It consists essentially in the provision of a two-part grid-leak of such total value as to prevent oscillation of the valves when all-in, due to the excess negative grid-bias cutting off the anode current, and in short-circuiting a portion thereof, by depression of the key, such as to bring the grid-bias to the correct working value. This is a better principle, for example, than complete disconnection of the grid-leak, as the resultant load-changes imposed upon the latter are much less heavy and abrupt, and not only is the leak itself relieved, but undesirable grid-click and "chirp" are eliminated, whilst the key load also is reduced and with it any sticking tendency. Moreover, in the position indicated capacity effects are *nil*, enabling the key to be connected to the transmitter by a length of flex and operated at any convenient distance without impairing the steadiness of note or adjustment of the transmitter, whilst H.F. burns of any consequence are practically impossible from any part of the key, a matter of some importance when any considerable power is in use. The absence of any "spacing wave" is also of practical importance, as the likelihood of interference with other stations is thereby reduced to half.

A suitable value of key leak will usually

be about twice that of the grid-leak proper, this consisting in the present case of a fixed resistance (whether non-inductive, non-capacitive or otherwise is of little moment if arranged as shown) of 30,000 ohms, the grid-leak itself being continuously variable between 2,000 and 20,000 ohms, and usually adjusted to a rather high value of the order of 10,000–12,000 ohms in practice owing to the use of plate voltages somewhat in excess of normal rating and operation on the constant voltage system, which is found advantageous. The key-leak and key itself are, of course, shorted for telephony, and it is important for this purpose that the grid-leak itself be constant and silent under load as a noisy leak can—and frequently does—quite spoil the purity of the carrier.

The transmitter described is suitable for powers up to about 100 watts, above which somewhat larger meters would be required, and forms an almost ideal medium-power set for use over a reasonably limited tuning range, although for ordinary purposes the loose-coupling arrangement would not be necessary and could be dispensed with without much effect on the efficiency, leaving a slightly modified Colpitts circuit particularly well suited to rapid wave-changing should this be desired.

A schedule of the actual outputs, etc., obtained in practice is here given :—

Watts	M.A.	V.	Oscillators	Aerial Current λ 160		
				A	I	E
10	20	500	2 "B"	1·75	·82	·93
100	83	1200	2 0·50	5·50	2·58	2·92

Two valves in parallel are normally used, as this enables a high efficiency to be obtained with considerable valve economy, the valves being run well within their limits and consequently having a long life, though to ensure best results it is very desirable that the filament temperatures be independently adjustable, as shown in the diagram, as no two valves possess quite the same characteristics, though once synchronised (which is done by oscillating them separately and balancing their outputs, etc.) all subsequent adjustments are affected simultaneously at the common control rheostat R so as not to disturb the balance, this being also much quicker and more convenient.

The neon side-tone shown in Fig. 4 may be noted, as this, being free from paralysis, affords really reliable indication of the modulation quality.

The next consideration was the H.T. supply of perfectly smooth D.C. at suitable voltage and wattage, it being essential for the purpose in view that this be both ample and completely free from ripple up to full load.

The house current being D.C. at 100 volts was not directly helpful, though being locally generated by a small hydro-electric plant costing little to run it is used at the station for the charging of the filament and H.T. batteries, the former of which consist of four Exide heavy-duty cells of 120-amps. actual capacity in glass containers, permanently mounted on an insulated rack and charged *in situ* through a resistance charging-board delivering up to 100 watts charging current, the battery delivering up to 12 amps. filament current at 8 volts without overload.

The H.T. battery, consisting of 250 cells of the B.K. type, is also permanently mounted on an insulated rack and charged *in situ* from the same source through a sub-charging panel delivering up to 75 watts charging current at 75 volts, the cells being series-parallelled in blocks of twenty-five for charging, and cascaded on discharge by means of a simple series-shunt switching arrangement, this plant providing a valuable source of perfectly pure D.C. up to 100 watts and 500 volts, and solving any difficulty up to that tension, being used for all the H.T. purposes of the station.

This sufficed perfectly for low-power work, but for greater powers a higher voltage was necessary, and this was provided by a 120-watt power transformer of 1-100 ratio built up from the coils of T.V.T. units, the primary of which is fed with 2 amps. of interrupted D.C. at 8 volts from the filament supply battery *via* a small motor-driven rotary interrupter delivering I.D.C. at a frequency of 400 p.p.s., to which the transformer windings are resonated, and this, after convertion thereby to 800 volts, is rectified and thoroughly smoothed by a special arrangement of neon tubes and a compound filter circuit.

A generator of this type, whilst producing maximum wattage in one direction, produces also a practically wattless half-wave in the

other, the voltage of which may reach up to half that of the useful half-wave, and this "backlash" requires to be completely suppressed either by rectification or polarisation for the production of pure D.C. suitable for telephony. The neon rectifier mentioned is employed only when the generator is used alone for intermediate powers, so need not be described here, the polarisation method being employed for full power, 500 volts from the H.T. battery described above being used for this purpose, this neutralising the backlash and pure D.C. at a voltage equal to generator+battery—circuit-drop being obtained. This is passed through a specially designed filter to eliminate the 400-period ripple, a feature of which is the compensating transformer C2, wound with 30 D.C.C., fluctuations across one winding of which give rise to equal surges of opposite polarity across the other, thereby strongly tending to neutralise any variations in the flow. The large condensers C1 and C2, of 4 mfd. each, were specially constructed to withstand an A.C. voltage of 3,000, and consist of 25-gauge sheet copper plates 12 ins. square in glass containers mounted on ribbed porcelain insulators, the dielectric being oil. Suitable means of discharging these when closing down are provided, as are also a glass-enclosed safety spark-gap across the secondary of the power transformer, set to flash at 1,000 volts, a fuse in the L.T. leads to the primary blowing at 2·5 amps. in the event of overload due to stalling of the interrupter, and one in the H.T. supply lead blowing at 150 milliamps.

Switch-gear is provided to cut out the generator and connect the battery alone for low-power work, and also to cut out the filter when tonic-train is required, the note produced being very clear and of good pitch.

This plant, the circuit of which is shown in Fig. 3, is capable of delivering up to 100 milliamps. of perfectly smooth D.C. at 1,200–1,250 volts, and is largely responsible for the quality of the results obtained, no ripple whatever being traceable on the carrier up to full load and voltage fluctuations due to load-change being negligible—a most important point.

The next and highly important considera-

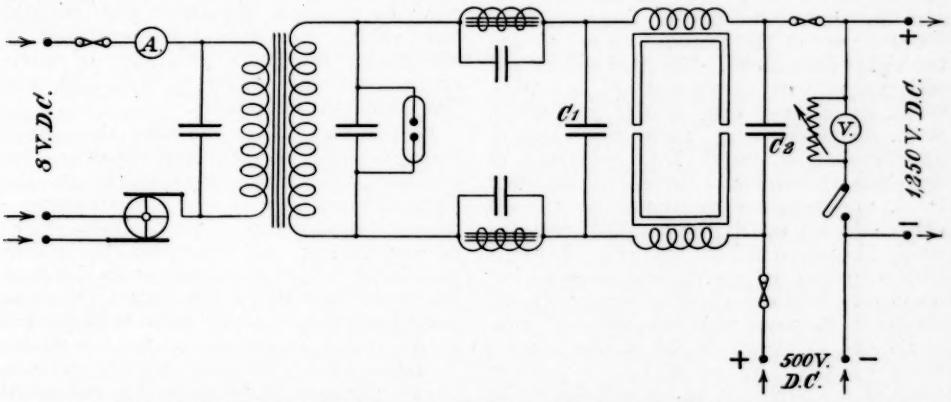


Fig. 3.—The generator and filter circuits. A milliameter, of course, is included in the main H.T. lead.

tion was that of control, it being necessary to modulate up to 80 watts or more with a minimum of distortion, and whilst little difficulty was presented by low powers of 10 watts or so with which choke-control could be used without too much wastefulness, this became a serious question where full power was concerned, as adequate control of a 100-watt transmitter by this system would necessitate the use of a 150-watt control valve with attendant increase in power consumption and expenditure. Grid-control, whilst economical, would not be suitable owing to the tendency to distortion and "spreading" of the carrier with this system, and after a series of experiments occupying a considerable time, in the course of which various systems and many permuta-

tions were brought into competition, choke-control was finally adopted for low power and absorption control for high, the chief trouble with this latter being, of course, harmonics. It is, however, a very economical system and capable of excellent results, the harmonic being actually avoidable, and grid absorption was ultimately adopted with complete success, although not often used with this type of oscillator.

To describe firstly the choke system—this is a fairly normal arrangement consisting of an iron-cored impedance specially wound to afford a flattish impedance peak at an R.M.S. speech-frequency in the neighbourhood of 800 p.p.s. at the input powers concerned, this somewhat low value allowing for the rather deep voice of the operator and the slight tendency of the resistance-coupled part of the amplifier to accentuate the higher frequencies. The choke is accordingly wound with 17,500 turns of 34 S.W.G. D.C.C. on an open core of soft iron wires, ·6 in. diameter, to an inductance value of 12 microhenries and a D.C. resistance of 850 ohms, the resonance curve being flattened by a non-inductive resistance of 100,000 ohms shunted across the winding, and the whole being sensibly aperiodic between wide extremes of speech and musical frequencies. It is connected in series with the anodes in the usual way, *via* two 0–50 milliammeters, as shown in the figures, control being exercised by an M.O./LS.2 valve in front of the amplifier, which will shortly be described. Control of grid-bias is effected in the manner described below.

The method of grid-absorption control used for full power is also shown in the figures, and will be seen to be quite normal, except that special means are adopted for correct adjustment of grid-bias on the control valve—a most important point—these taking the form of an iron-cored choke shunted by a non-inductive resistance of ·5 megohm, *via* which the necessary bias is applied from a battery tapped at each 1·5 volts, without appreciable leakage of the speech currents, the control valve itself being a Western Electric 208/A—a dull-emitting power amplifier of large emissivity, capable of full control of a 100-watt transmitter when used in this manner. A sensitive galvanometer in the grid-circuit of the control valves indicates the existence of any grid current in either case.

The speech amplifier used in both cases is now to be described, and consists of three valve stages coupled as shown in Fig. 4, the first two stages being resistance-coupled and the sub-control impedance-coupled, the stages being stepped progressively with regard to plate voltage, etc., to obtain correct and efficient operation of each. The voltage applied to the amplifier as a whole is 120, this being delivered to the valve plates *via* the resistances and choke of suitably apportioned resistance values, the capacity couplings being also apportioned so as to ensure maximum aperiodicity of amplification, the choke at the sub-control stage being suitably designed and shunted by a N.I. resistance of ·25 megohm to the same end, each valve being adjusted to the correct operation point by provision of suitable grid-leak and bias values, etc., care being exercised in the design to ensure avoidance of inter-circuital reaction effects at both high and low oscillation frequencies.

Dull-emitter valves are used throughout owing not only to considerations of current economy, but more particularly to the silence in operation of valves of this type—a most desirable feature when several stages of amplification are concerned, the valves used being AR-06 at the first stage, DER at the second, and B4 for sub-control, the mean amplification factor per stage working out at 6·2 and aggregating 240 for the whole. A tapping-plug allowing 'phones or L.S. to be plugged in provides for individual checking of amplification and quality at each stage.

So large an amplifier for the modulation of 10—or even 100—watts may seem unnecessary, but it should be pointed out that the degree of magnification per stage has been purposely limited to a fairly low figure for the avoidance of distortion—amplification being in practice well sustained within extremes exceeding 300 and 3,000 p.p.s., and the amplifier being, in fact, practically distortionless—and that the microphone used is not of the carbon type, but is a special instrument of much less current displacement capacity, which will now be described.

This microphone is a magnetic instrument of not very usual type operating by a damped diaphragm vibrating in a permanent magnetic field, producing corresponding

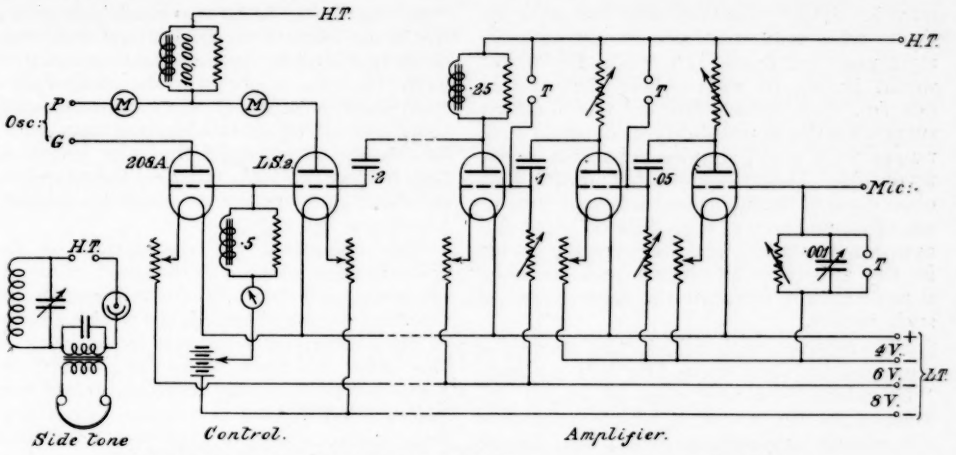


Fig. 4.—The special apparatus used in the distortionless amplification of the speech potentials.

current surges in field-coils wound therein, which are delivered direct to the amplifier. The coils are wound to a resistance of 4,000 ohms, and the field currents themselves operate the amplifier, there being no applied current other than the small negative grid-bias to the first valve thereof, which does not constitute a load proper but does operate in small degree to increase the field intensity and so also the sensitivity of the instrument. The diaphragm is of special construction, and is aperiodic between considerable limits of speech and musical frequencies, automatic compensation being provided in an effective and somewhat original manner, giving considerable freedom from distortion without undue loss of efficiency. The clearance between diaphragm and pole-pieces, which are collectively circular in shape to exert centre pull, is finely adjustable in operation by means of an external milled screw, input to the amplifier being adjustable by means of a continuously-variable resistance across the field-coils, *e.g.*, across grid and filament of the initial amplifier valve, across which is also shunted a variable float-condenser of ·001 mfd. maximum capacity to provide adjustable frequency compensation and absorption of sonic harmonics. The energy derived from an instrument of this type is, of course, considerably less than with a carbon microphone, and consequently requires greater amplification, but the results are infinitely superior if care be exercised in the design and adjustment of the amplifier, whilst the usual "packing" tendency is, of course, entirely absent. The principle of operation is shown in Fig. 5, in its simplest form.

The instrument described, which is the outcome of considerable experiment, is sensitive to speech at 6 ft. and to music at about double this, and is normally set to afford full control at about 18 ins., which is the working distance adopted in practice, no mouthpiece being used and the operator merely speaking towards it in normal tones, this considerably reducing the usual "blasting" tendency due not only to periodicity in the apparatus used, but to actual accentuation by the speaker of certain tones, to which, however accustomed the ear, the microphone is uneducated. The instrument itself is in the present case suspended by tensioned rubber straps in a frame mounted on a cushioned stand placed beside the operating bench for the avoidance of jars and mechanical vibration to which, though considerably less sensitive than a carbon microphone, the size of the amplifier renders it somewhat susceptible; and it is in this connection worthy of note that the valves of the amplifier are themselves cushioned and damped for the reduction of microphonic noises, which eliminates any tendency for the amplifier to "howl" from this cause.

This completes the description of the transmitting arrangements, and, whilst these

may be thought unnecessarily elaborate by those who may not yet seriously have attempted telephonic DX work, the writer would hasten to assure them that this is not so; and, whilst not for one moment suggesting the impossibility of covering long ranges with much simpler apparatus under favourable conditions, would urge that observance of the main considerations governing effective carry of a modulated wave and appropriate attention to the necessary details in the apparatus producing and receiving it must greatly facilitate the achievement of such results.

The receiver with which the station is equipped for short-wave DX is a six-stage "Ultradyne"—a new class of circuit developed by the writer of which space does not permit a description here; but the use of such a receiver is, of course, by no means essential, and adequate results should be obtainable with any normal arrangement of sufficient sensitivity if correctly designed and worked—a super-heterodyne receiver, for example, being particularly suitable and strongly to be recommended for short-wave DX. But whatever arrangement is used, it is essential that it be stable in operation, selective, highly sensitive, and as free as possible from distortion and internal noisiness, as these latter will render the most sensitive of receivers quite useless for really long-distance low-power telephony—in which connection it may be mentioned that, in the writer's case, not only are dull-emitter valves used throughout, but only one stage of audio-frequency amplification is used, and that is not transformer but impedance-coupled both as regards input to valve and output to 'phones, even this being frequently disused when QRM or QRN are at all in evidence, in which case a 15 ft. × 10 ft, indoor and a 6 ft. frame aerial are available and sometimes used.

It will be unnecessary to enter into remaining details of the station, except to state that all possible precautions against stray capacity effects are taken both within and without, the change-over switch, for example, which controls both receiver, transmitter and generator in a single operation and enables instantaneous changes to be made, whilst itself mounted in a convenient position on the operating bench, operates the aerial switch through a magnetic relay, the latter being mounted high above the bench close to the lead-in and well clear of all undesirable capacities and straying of leads, the same applying to the counterpoise lead, which is kept well away from the earth strip and all other trouble, the apparatus, etc., being so arranged that the length of high-frequency leads within the room is as short and direct as possible—actually a very few feet only.

This completes the description of the special means adopted in the quest of super-efficiency, and their effect is reflected in the practical results obtained, the working range of the station on a 10-watt input being of the order of 1,000 miles and telephonic communication having been established with places as far distant as Norway, Switzerland and Spain; whilst on 100 watts not only has an entire test transmission, sent out on telephony on the morning of December 13 last, when the transmitter was first tested on full power, been received at and fully reported from Boston, U.S.A., but two-way trans-Atlantic telephony was, on the morning of January 20 last, successfully established, it is believed, for the first time in history—though this is of less importance than the fact that its establishment on so low a power is thereby proved to be already possible by quite standard methods and at small cost, furnishing additional evidence of the advance made in radio science during the last few years—one may even say months; and it is gratifying to note how much of this has come at the hands of amateurs, the achievement of British 2OD, for example, in establishing trans-Atlantic telegraphic communication on a power as low as 32 watts, being an epoch-making one in the history of the science, either amateur or professional.

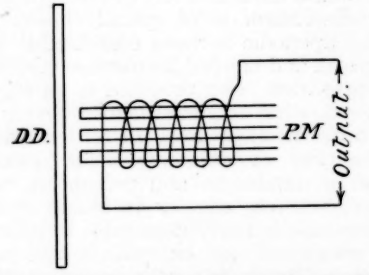


Fig. 5.—Illustrating the principle of the magnetic microphone.

Everything in the present case, with the exception of a few minor items, having been designed, constructed and installed by the writer single-handed and at strictly reasonable expense, it is hoped that this may, perhaps, encourage other amateurs to emulate on telephony the great things they have already done for radio on telegraphy; and in this connection the writer offers it as his considered opinion, formed as a result of considerable investigation of the subject, that reliable telephonic communication across the Atlantic is quite within the bounds of possibility on powers as low as 10 watts, and further ventures the prophecy, based on a knowledge of the ability and enterprise of the amateur experimenter, that such a result will, in fact, be achieved within a period of two years—by amateurs.

The Month's "DX."

Recorded by HUGH N. RYAN (5BV).

The increasing efficiency of amateur transmitters and receivers is resulting in the creation of many new long-distance records which are undoubtedly worthy of mention. It is proposed to record month by month work in this direction, and the Editor will be pleased to receive details for inclusion in these pages.

AT the time of writing last month's notes we were still sufficiently in the thick of the first trans-Atlantic rush not to have had time completely to collect all the results which had been obtained, or to realise fully the extent of the good work which had been accomplished.

This being so, and conditions being now more settled, it may not be out of place here to give a *resumé* of trans-Atlantic work up to date.

Before the end of 1923 2KF, 2SH, 2OD, and 5BV had established two-way communication with the United States and Canada.

Since then the same result has been achieved by the following: 2SZ, 2NM, 2FU, 5NN, 5KO, 2KW, 2WJ.

The list of stations heard in the States during the official tests remains as given last month, since for some reason the R.S.G.B. appears to have dropped the subject and no further reports have been issued.

The results would, no doubt, have been even better but for the fact that from about January 26 until February 8 we had a spell of very bad conditions, during which trans-Atlantic work was practically impossible on any scale, though 2OD managed to keep up communication with Canadian 1BQ most of the time.

A number of additional American stations have entered the field of two-way working. Our old friend 1CMP, famous for his countless CQ calls on 200 metres, has now come down to the lower wave lengths. His programme at first consisted of further CQ calls, which many of our stations answered, without success. His reception has now greatly improved, however, and he now receives 2KF, 2OD, 2KW, and 5BV, having often effected two-way working. One wonders how many thousands of times 1CMP was called by British stations during the latter months of 1923 when his calls were such a familiar feature of the night watches! It is with a particular satisfaction that we connect with him after so many months of calling.

The distinction of being the American station heard best in England has kept changing from one to another. In the early days of two-way working 2AGB probably held the position. It then became the turn of 1XW. At present by far the strongest station I receive myself is 1XAM (Reinartz's Station), but 2KF finds 1BDI the best.

Many of us remember 1BDI as one of the star stations in the 1922 tests, and are glad to hear him again, especially as he can now hear our signals and reply!

In last month's notes I mentioned the large number of Americans worked by 2KF. He has not only maintained his lead, but

greatly increased it. Here is his list to date: 1XW, 1XAM, 1XAQ, 1CMP, 1BDI, 2AGB, 2AWS, 2CFB, 3XAO, 3OT, 8XAP, 9AZX, Canadians 1BQ and 3BP.

And the North used to say London couldn't work DX! 2KF's telephony has been received weakly by 1CMP, and strongly and clearly by 1BDI.

Dutch PCII is still working Americans regularly nearly every night. I am not sure how many he has worked, but the number is fairly high.

Another well-known Dutchman, PCTT, whom some of us had the pleasure of meeting in London recently, is now going again, and should get over soon. During the tests PCII and PCTT combined their apparatus to make one station at PCII.

Of the French stations, 8AB is still working, but is not heard so much as he was a month ago. 8CT, of Arcachon, who was heard in America during the tests, on 200 metres, has now reduced his wave-length, and is very strong indeed. The last time I heard him he was trying to connect with 1XAR, but I do not yet know whether he has been successful.

Some listeners on this side have been confused by the fact that some American stations on the short waves are apparently operated by men from different stations on 200 metres. The reason is that all American stations licensed for 100 metres are given a special call-sign for that wave-length, beginning with the letter "X."

Thus 1XW on 100 metres is the same station as 1MO on 200 metres. 1XAM is 1QP of 200 metres, and 1XAR is 1BDT of 200 metres.

Much more could be written about American work, which has become so absorbingly interesting to us all, but I think I have occupied enough space with it already.

In spite of the great interest in American work, much that is interesting is happening in European DX.

After becoming used to working the States, our stations have become so expert that European stations, which we worked with some difficulty two months ago, now seem quite "local."

It is interesting to look back, say, less than two years. In those days we were quite excited at working a French or Dutch station. An envied few could connect with 8AB, but most of us considered ourselves lucky if we were in the reports from Denmark, which were then just beginning to arrive. Our "testing" was usually carried out with a station a few miles away at most, and not until we had our sets tuned up to their very best did we venture to call a Frenchman. We now carry on most of our testing with Dutch or French stations, who are read with ease, and who can be "raised" with a single short call. Our only concern with the local stations with whom we used to do all our testing is now to tune them "out" instead of "in."

Italy, the latest country to possess amateur transmitting stations, is already doing very well. IMT (Venice) has worked a number of our stations. ACD, mentioned as an unknown station in last month's notes, is also in Italy (Bologna).

I believe he has, so far, only worked with two British stations (2KF, 5BV) and one Dane (7ZM), but he has received signals from a large number of British and French stations. He has also received telephony from 2KF.

One station (1JW) has started up in Luxembourg, and he has worked a number of British stations. I have received an enormous number of letters from British stations, saying that he was a new Italian station whom they had received! His signals are very strong everywhere in England.

The number of French stations has greatly increased recently. One of them, 8OH, is run by some soldiers in the French Army of Occupation at Wiesbaden. It is a useful station for testing the transmissions of those of our men who want to get further than Holland, but cannot reach Italy.

Now for what our own stations are doing. 5KO has been doing very well in trans-Atlantic work. He started a bit late, and is apparently trying to make up for it, with interest. He has, as far as I know, only worked one American (1XAR), but he has been received by a large number of them, including 3APV, Washington, and Canadian 9AL, Toronto.

5DN has worked XY (Geneva) again several times.

Mr. Niell, of Belfast, is still doing very well in reception. In addition to those mentioned last month, he has now received telephony from 2KT, 5DT, 2PX, 5IC, 5TR, 6NH, and 5BV.

5QV has worked French 8CJ on telephony, which 8CJ reported as being very clear.

M. Alphonse Boutié, of Ain Tedèles, Algiers, has received signals from a number of British stations. I have not the full list at present, but it includes 2JF, 5KO, 6RY, 2NM, and 5BV.

Now, just at the end, so that the shock you get on reading it won't matter, I will mention the ambition which is forming in the minds of several of our men, and that is direct transmission to Australia. It sounds pretty hopeless at first, but consider the facts. When we first started up on 200 metres it took us about a year to realise its possibilities, and nearly two years to do any useful DX. Yet within a month or so of "discovering" the shorter wave-lengths we are working regularly with Americans and Canadians, at ranges up to 5,000 miles. Then why, as we get more knowledge of the short waves, which we are rapidly doing, should we not increase the 5,000 miles to 12,000? 2KF and I have now met two of the Australian transmitters, and from their accounts it appears that they are blessed with splendid conditions. The foremost of their transmitters, Mr. McClurken, has worked with New Zealand, 1,100 miles, on 250 metres, with an input of ·004 of a watt!

If they can do that, then I prophecy that they will hear us within two years. But if European amateurs do get through to the Antipodes, let us see to it that the British stations do it first.

Apart from direct work, we are fixing up a relay to Australia through the United States and Honolulu. All the individual links in the chain are working, that between Honolulu and Australia being the weakest, and it is only a question of whether we can connect up before the season this side gets too late. We do not yet know whether we shall be able to keep up communication with America during the summer, but we hope for the best. After all, we first connected with France and Holland during winter months, but kept it up ever since, so why not America?

It is, at any rate, sure that we who are concerned with DX are having the most interesting time we have ever had before, or are likely to have again.

The Position of the High-Tension Battery.

A rough glance at a large number of receiving circuits will probably show that the negative end of the high-tension battery is as likely to be connected to the positive side of the filament as the negative side. When connection is made to the positive side of the filament the potential of the anode with respect to the negative end of the filament is certainly increased by about an additional five volts, but with an ordinary hard valve and a plentiful supply of high tension, there is no need to desire extra high tension from this source. There is, however, no objection to this practice in itself, but connection to the positive filament greatly endangers the life of one's valves if any experimental work is done. Whatever form of inter-valve coupling is employed there are always leads from the positive high tension and negative filament. In substituting another transformer, for example, or making any alteration whatever with loose wires, there seems to be nothing easier than to allow the positive high tension lead to come into contact with the negative filament.

Consider now the case in which the negative high tension is connected to the negative filament. The high-tension battery is merely short-circuited, which is indicated by a click and a flash. The battery suffers little damage. When connection is made to the positive side, however, conditions are very different. The battery is once more short-circuited, but this time through the filament battery. In other words, the full high tension is applied direct to a filament already near the point of fusion. There is little hope for the filament if the high-tension battery is at all new. The remedy is obvious—namely, connection to the negative filament. Of course, if in addition there is a lead from a grid leak to the positive filament one cannot then afford to be careless at all!

Dutch Amateur Transatlantic Tests.

BY A DUTCH CORRESPONDENT.

An examination of Dutch methods shows that the circuits employed, both for reception and transmission, vary considerably from our own. Below one of our Dutch correspondents summarises their work in the recent Transatlantic Tests.

DURING these trans-Atlantic tests, too, transmitting had not yet been permitted to the Dutch amateurs, and most of us were only allowed to listen for our English and French colleagues. Only to the Dutch station PA9 was an official licence awarded. This station belonged to the Technical High School at Delft, and had an input of 500 watts.

The amateurs who possessed a transmitter, however, did not mind this prohibition, and all risked trying to bridge over the ocean, except station oMX, who had a call after some days of testing of an official of the telegraph service and a detective. He was compelled to give up his A.R.R.L. testing, and only to listen for his colleagues, a very grievous thing for a thorough amateur.

Of the Dutch amateurs the stations PCII, PA9, PAR14, oDV, oAR and oYS were the principal transmitters, of which PCII, PA9, PAR14 and oDV had good results, while till this moment it is not yet known whether the stations oYS, oMX, oFN and oAR bridged the ocean or not.

We will give now some descriptions of

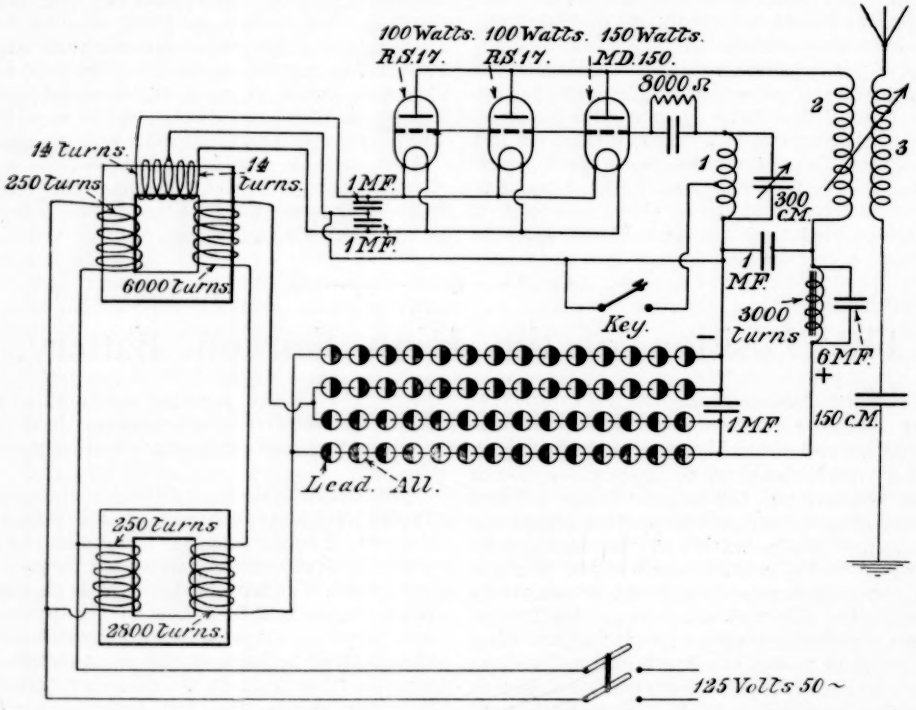


Fig. 1a.—The transmission circuit employed by PCII.

some Dutch transmitting stations which got success, especially on a wave-length of 100–130 metres. Their attention having been drawn to results of French 8AB, which worked very successfully with American 1MO and 1XAM on 135 metres, and, after this, the success of English 2KF, the Dutch amateurs also lowered their wave-length from 200 metres to 100–130 metres, with the result that the most of them had less antenna current, but with the advantage that the well-known fading effect almost disappeared and that their radiation was better.

Station PCII was the first Dutch station on 112 metres, and succeeded in working with American 2AGB for two hours in the morning of December 28. In the beginning PCII worked on 200 metres with one 150-watt "Mullard" transmitting valve, with 3·5 amps. in aerial. After lowering his wave to 112 metres, the aerial current was only 1·6 amps. For all that, he was reported with this antenna energy. After this result PCII increased his transmitter by a second 1,500-volt transformer, and raised the solution of his electrolytic rectifier (ammon. phosph.) from 7 to 12 per cent. Parallel with the "Mullard" of 150 watts two 100-watt valves ("Telefunken") were placed so that the total input was about 350 watts, with 2,100 volts on the plate and 2·75 amps. in

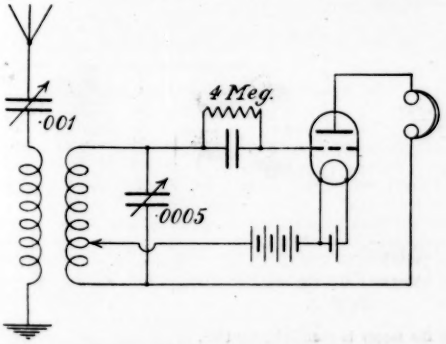


Fig. 1b.—Receiving circuit used by 0AR.

aerial. The plate circuit is inductively coupled with the aerial; this was done to prevent variations of wave-length by swinging the antenna (Fig. 1a).

The aerial of PCII consists of four wires, 21 metres long, one end attached to a pole 21 metres high, the other end to the roof of his house. Below the aerial is a counterpoise of five fan-shaped spread wires, 4 metres above the ground.

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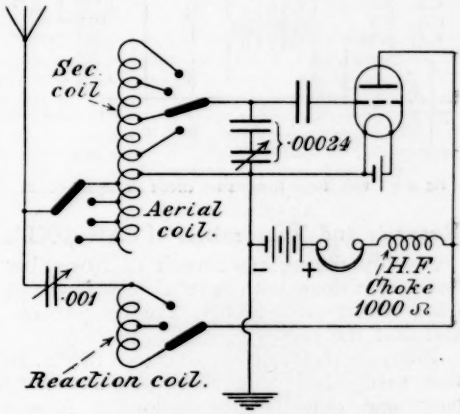


Fig. 2.—A modified form of Reinartz receiver.

900 watts input and 4 amps. aerial current. After some testing PCII delivered a message from the Dutch Radio Society, containing greetings to the A.R.R.L. The signals of 2AGB were strength 6 on one detector and a two-valve low-frequency amplifier. On December 29, 0450 G.M.T., 2AGB called PCII and gave qsa, but qrm qsu half hour cu half hour, 0533 G.M.T.; 2AGB gave still qrm, pse qsu few minutes more vy sri om. At 0550 G.M.T. 2AGB gave, after calling: qrm very bad, will come back to-morrow. At 0637 G.M.T. 2AGB called PCII: This is all right nw, qst fb. k. After this they had connection till 0715 G.M.T. On December 30 tests with C1BQ, but strength of signals too weak at break of day

Fig. 1a shows the transmitting circuit of PCII. Coil 1 is the grid coil, consisting of ten turns on a coil of 20 cm. size. It is not necessary to couple this grid-coil with the plate-coil.

Coil 2 is the plate-coil, nineteen turns on a coil of 18 cm. size, and coupled with the antenna-coil 1, of $3\frac{1}{2}$ turns, wound on a coil of 13 cm. size. Keying is accomplished by shorting some of the grid-coil.

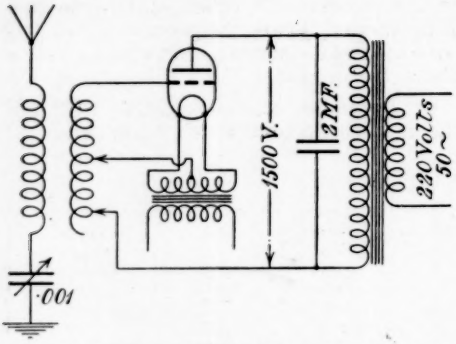


Fig. 3.—A very simple transmission circuit employed by 0AR.

Receiver and Transmitter of 0AR (0XL).

Already during the month of November tests were done with several receiving and transmitting circuits to make comparisons and find the best.

First, the receiving circuit shown in Fig. 1b was used of French 8BV origin :—With only one detector the following American amateurs were heard : 1ANA, 1CDU, 1AW, 2BD (very qsa), 1BWJ, 2BSC, 1BCF, 8SZ, 1BLN, 1WL, 8CDC, 2BQH (qsa), 2WA, 8CKO, 3MO and 2CXL.

Generally, a counterpoise was used some metres above the roof. This slightly corrected the reception, because the local qrn decreased and at the same time a sharp aerial tuning was obtained. During the transatlantic tests a Reinartz receiver was mounted, with this difference—that the inductance was not a basket coil, but a common cylindrical coil (Fig. 2). The size and length of this coil is about 8 cm. The coil is vertically mounted in the set, and is wound with 3×15 turns for the plate circuit, 5×1 turns for the aerial, and 65 turns for the grid circuit, tapped at 16, 24, 34, 46 and 65 turns. The plate- and grid-coil are wound in two layers, the so-called "bank-wound." The wire used was litz wire, about 0·8 mm. size.

Maximum wave can be lowered by bridging the non-used part of the grid-coil, and as long as the bridged coil is not tuned on the wave on which one wishes to receive one will not be troubled by it.

The smoothing-coil is made of copper wire, 0·07 mm. size, and to a total resistance of about 1,000 ohms.

In series with the secondary condenser of 600 cm. a condenser of 400 cm. is placed, by which the maximum capacity of the

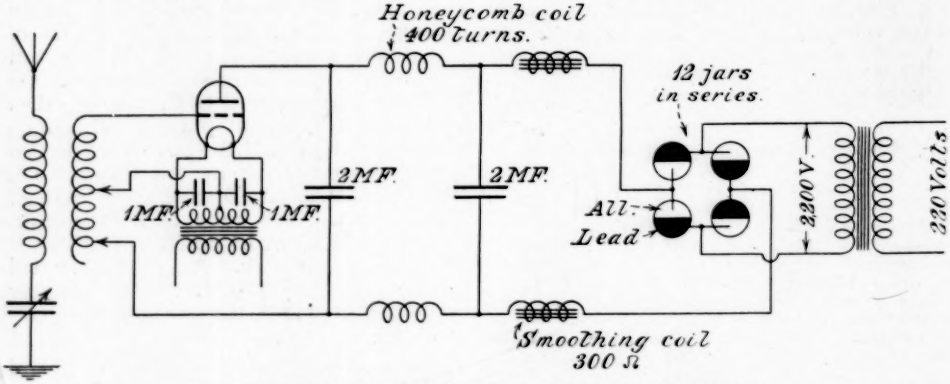


Fig. 4.—A modified form of Fig. 2 in which the supply is chemically rectified.

The primary coil of this circuit had twenty-four turns, while the secondary coil had forty turns litz wire wound on a coil of 8 cm. size. The strength of the signals with this circuit was very good, but tuning was difficult, as the aerial coupling had an influence on the oscillation of the valve.

secondary condenser is about 240 cm. This is of great importance for receiving very short wave-lengths.

With this receiver and one detector 0AR heard the following American amateurs on the morning of December 2 :—1BEP, 1XAM (on 100 metres very qsa), 2AWF, 8NB,

the headphones gave very good quality reproduction and fairly good strength considering that four pairs were in operation simultaneously. The tone is rather on the deep side, but is certainly not too deep. We were not quite so pleased with the volume from the loud speaker, but on normal load the quality was quite good. After being accustomed to ordinary telephone leads, the comparatively heavy flexible tubing seemed to make its presence well known ; perhaps it might be possible to substitute it by rubber tubing. The Barnes' Multiphones should appeal to those interested in headphone reception of broadcasting, since four pairs of telephones and a loud speaker are available at practically the same cost as that of a small loud speaker.

Showing the construction of the switch on the Fuller Tone Controller.

* * *

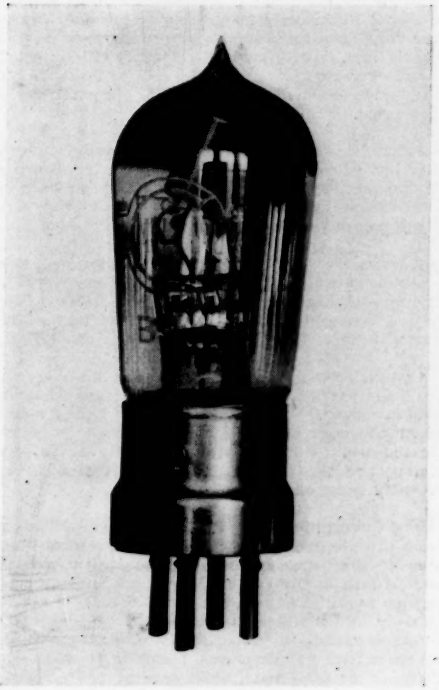
THE FULLER TONE CONTROLLER.

We have received for test from Messrs. Fullers United Electric Works, Ltd., one of their standard tone controllers, which is shown in the accompanying illustration. As its name implies, it is intended to control the tone of music or speech in the telephones or loud speaker. It will be seen that there are two input and two output terminals, which are connected respectively to the output of the set and the telephones or loud speaker. The device is fitted with a special six-leaf radial switch, which connects in parallel a number of studs communicating with a series of condensers connected in parallel with the input and output terminals. In operation it is found to be very effective in altering the tone of the received signals, and in particular one can usually find a best setting for speech and a best setting for music. To those of refined musical tastes it should make a special appeal.

* * *

ANOTHER ORA VALVE.

The O.R.A. "A" and O.R.A. "B" valves are too well known to need any introduction to our readers. Another has now been added to the group in the form of the D.F. O.R.A., which is somewhat similar to the original types, but is made with a thoriated high-resistance filament similar to that used in the UV199. The shape and position of the electrodes can be gathered from the accompanying photograph. The filament current is 60 milli-



The new D.F. Mullard ORA.

amps. at 2 to 3 volts, with a fairly heavy emission, as much as about 12 milliamps. being obtainable. With 100 volts on the anode a grid-bias of about 5 volts is required when used as an amplifier. The valve should be especially useful for compact portable sets where battery power is limited. We would remind our readers that a valve with so thin a filament requires very careful handling.

Experimental Notes and News.

The next Wireless Exhibition under the auspices of the National Association of Radio Manufacturers will be held at the Royal Albert Hall, London, during the last week in September next and the first week of October. It is intended to demonstrate present-day wireless achievement under the best possible circumstances.

* * *

The time signals broadcast from London are now sent direct from Greenwich Observatory, instead of from Paris.

* * *

The morning broadcast concert from 2LO is to be resumed at an early date. This is a concession to night-workers who are unable to listen to the usual programmes.

* * *

Sir Henry Thornton, the President of the Canadian National Railways, is arranging to provide wireless receiving sets for 100,000 workers on that company's line. Broadcasting stations will be established at various points of the 22,000 miles of railway, and sets will be supplied to the workers at cost price.

* * *

It has been stated that over 12,000 miles of aerial wire have been erected in Britain during the past twelve months. Over £100,000 has been paid by the British Broadcasting Company in fees, copyright royalties, and salaries for the wireless concerts.

* * *

Australia's first broadcasting station has been established at Willoughby, eight miles north of Sydney. A cage aerial 575 feet long, is used, supported between two towers 200 feet high. The wave-length is 1,100 metres, and the call is 2FC.

* * *

Complaints of oscillations in the London area are recorded at B.B.C. headquarters by inserting pins in a map. The pins are removed once a month when the complaints have been investigated and cleared up. Forest Gate, Stratford, Acton, and Ealing are the districts where most trouble has recently been experienced.

* * *

The Government of India are inviting applications from private enterprise for licences to establish and operate the necessary radio service to provide the Indian link in the Imperial Wireless Scheme. The service required entails the installation of a station capable of conducting high-speed duplex radio communications in two directions simultaneously, together with simultaneous reception from at least three other directions, at a rate of charge which shall not exceed the cable rates from time to time prevailing. Direct communication with the United Kingdom or South Africa on the one hand, and Australia or Canada on the other, must be guaranteed.

* * *

It is stated that owing to the depression in the shipping industry, more than 2,000 competent marine wireless operators are unemployed. On the other hand, there appears to be a shortage of operators in the Royal Air Force. In the latter service, all wireless operators will be given the rank of Leading Aircraftsman or Aircraftsman (First Class) as soon as the attestation test has been passed, according to the skill shown. This carries with it pay at the rate of 5s. 2d. or 4s. 6d. a day. All operators are fed and clothed. By attaining the rank of first-class sergeant-major it is possible to obtain pay at the rate of 15s. a day.

* * *

The Liverpool Relay Station is to be constructed immediately after the completion of the Edinburgh Station. B.B.C. engineers have already visited Liverpool to examine possible sites.

* * *

The British Broadcasting Company are considering the establishment of a new high-powered broadcasting station just outside the London area. The proposal is to put up a 25-kilowatt plant, working on a wave-length of 1,600 metres. It is thought that the new station, if definitely proceeded with, will facilitate crystal reception up to 100 miles, single-valve reception up to 200 miles, and two-valve reception anywhere in the United Kingdom. Permission has already been given by the Postmaster-General to erect such a station for experimental purposes. A permanent license would be subject to the new transmission not interfering with Government services.

* * *

Dundee is anxious to have a relay broadcasting station. A sub-committee of the Town Council has been appointed to interview the G.P.O. officials and others in connection with the scheme.

* * *

A demonstration of a new device for preserving the secrecy of wireless messages has been recently given in Birmingham. The device provides for the reception on one aerial and one receiver messages of two, three, or any number of different wave-lengths. By transmitting messages of which the alternate words were on different wave-lengths, in accordance with an agreed code, secrecy would be preserved.

* * *

The Housing Committee of the London County Council have decided to dispense with the deposit which was required from tenants desiring to instal wireless apparatus. A deposit of £1 is, however, still required from tenants of block dwellings.

* * *

On a recent trip of the *Aquitania* the wireless aerials were arranged to work one on 600 metres and the other on 1,200 metres. By working a double shift, messages were handled with much greater ease than usual, and during the voyage 100,000 words were transmitted as against 60,000 on a normal voyage.

* * *

Complaints are being made that the Radio Corporation of America have established a monopoly in wireless apparatus in restraint of trade. The Corporation comprises a number of the leading wireless manufacturing companies in the United States, and the Federal Trade Commission has entered a charge against them.

8CKN, 8CEI, 1CMP (calling French 8AB), 2RK (qsa), 1XM (on 100 metres very qsa), 2BD, 9VM and 9AN.

For transmission 0AR (a combination of three amateurs) used the following circuit (Fig. 3). The primary coil had 25 turns, wound on a coil of 12 cm. size. The grid-coil had 25 turns, wound on the same coil of 12 cm. size. The high tension used for the plate was full alternating current, without any rectifying. With three 10–20-watt valves ("Telefunken") an aerial current was obtained of 2·5 amps. on a wave of 210 metres.

The note was very bad because of the terrible "hum" of the alternating current, so that 0AR looked for a rectifying method. Some days before the trans-Atlantic tests the following corrections were made (Fig. 4): The primary coil and the grid-coil were changed into ebonite crosses, round which concentric hoop copper was wound. The two coils were fixed on hinges so that the exact coupling was easily found. The high tension of 1,500 volts was changed into 2,200 volts and rectified by an electrolytic rectifier (ammon. phosph. 10 per cent. solution), making use of the so-called "Grætsche circuit," to rectify the two phases of the alternative current.

Two high-frequency chokes were placed in the high-tension leads. The chokes were common honeycomb coils of 400 turns. By this the plate current decreased 50 milli-amperes. Condensers of 1 mfd., placed across the two halfs of the filament turns, made the note clearer.

After these corrections an aerial current of 2 amps. was obtained on a wave-length of 130 metres.

The aerial used was 20 metres long, 16 metres above the roof by means of two wooden masts. Below the aerial is a counterpoise of six wires, 25 metres long, 2 metres above the roof.

Transmitter and Receiver of oDV.

Fig. 5 shows the old transmitter of 5 watts, with which the first results were obtained. The high-tension transformer is on the table in a tin-lined iron box, filled with oil. Against the wall we see the unmounted 5-watt valve, the transmitting spider-web coils, and filament-plate and aerial-current ammeter. Near the transformer is the high-tension condenser of 2 mfd. The transmitter is visible mounted, as shown in the photo. All parts were made by himself, except the valves and ammeters. The antenna was a cage-aerial, 30 metres long and 16 metres high. A counterpoise was used of five wires and 50 metres long, which was used together with the common water-pipe earth.

Some days before the beginning of the tests the transmitter was fitted out with

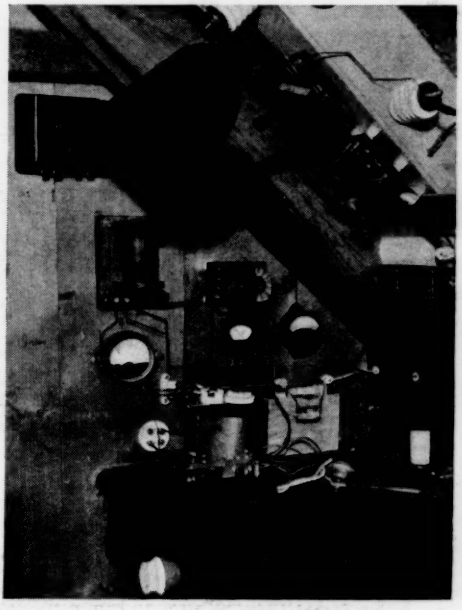


Fig. 5.—The original transmitter at oDV.

two 10–20-watt valves, and a new high-tension transformer was built.

To get a shorter way of his aerial to his transmitter the whole transmitter was removed to another corner of the room and was mounted there in haste, because it was one day before the tests (Fig. 6). To get the 100-metre wave the aerial must be shortened to a length of 12 metres and the counterpoise kept at a length of 50 metres. Especially the shortening of the aerial was accompanied with great trouble, in a very severe frost and snowstorm, during the A.R.R.L. days.

Fig. 6 shows the transmitter with which oDV bridged the ocean. To the right of

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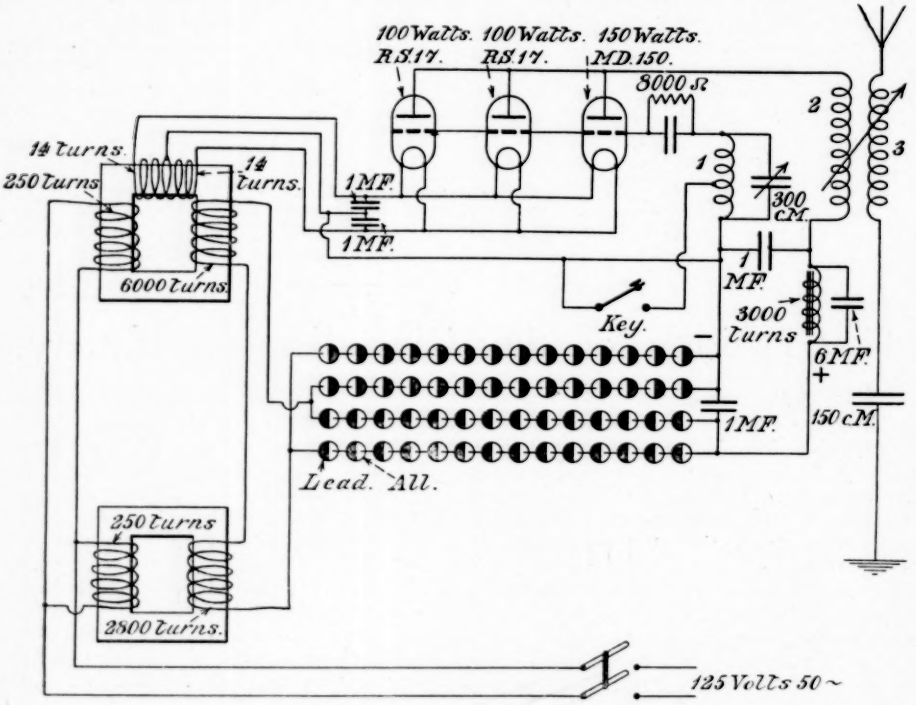

Fig. 1a.—The transmission circuit employed by PCII.

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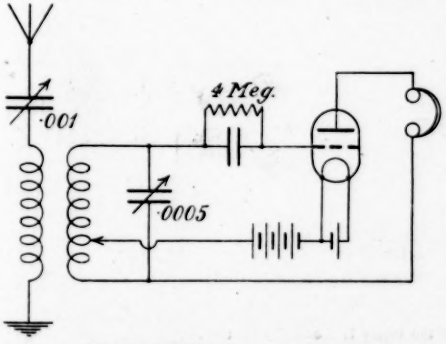

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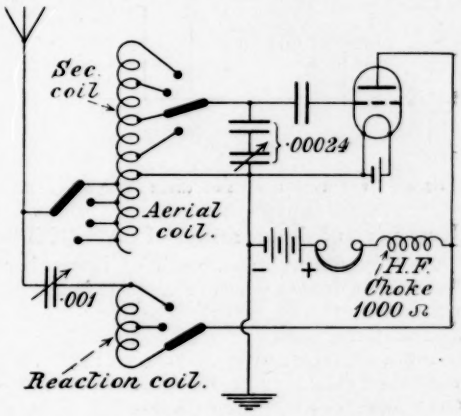

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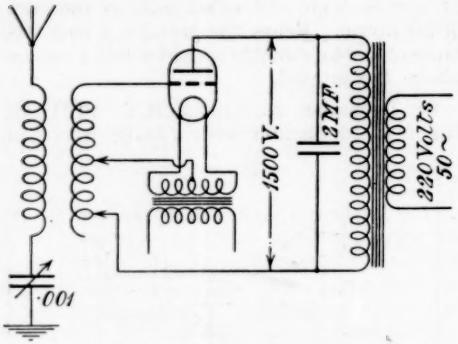

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Already during the month of November tests were done with several receiving and transmitting circuits to make comparisons and find the best.

First, the receiving circuit shown in Fig. 1b was used of French 8BV origin :—With only one detector the following American amateurs were heard : 1ANA, 1CDU, 1AW, 2BD (very qsa), 1BWJ, 2BSC, 1BCF, 8SZ, 1BLN, 1WL, 8CDC, 2BQH (qsa), 2WA, 8CKO, 3MO and 2CXL.

Generally, a counterpoise was used some metres above the roof. This slightly corrected the reception, because the local qrn decreased and at the same time a sharp aerial tuning was obtained. During the transatlantic tests a Reinartz receiver was mounted, with this difference—that the inductance was not a basket coil, but a common cylindrical coil (Fig. 2). The size and length of this coil is about 8 cm. The coil is vertically mounted in the set, and is wound with 3×15 turns for the plate circuit, 5×1 turns for the aerial, and 65 turns for the grid circuit, tapped at 16, 24, 34, 46 and 65 turns. The plate- and grid-coil are wound in two layers, the so-called "bank-wound." The wire used was litz wire, about 0·8 mm. size.

Maximum wave can be lowered by bridging the non-used part of the grid-coil, and as long as the bridged coil is not tuned on the wave on which one wishes to receive one will not be troubled by it.

The smoothing-coil is made of copper wire, 0·07 mm. size, and to a total resistance of about 1,000 ohms.

In series with the secondary condenser of 600 cm. a condenser of 400 cm. is placed, by which the maximum capacity of the

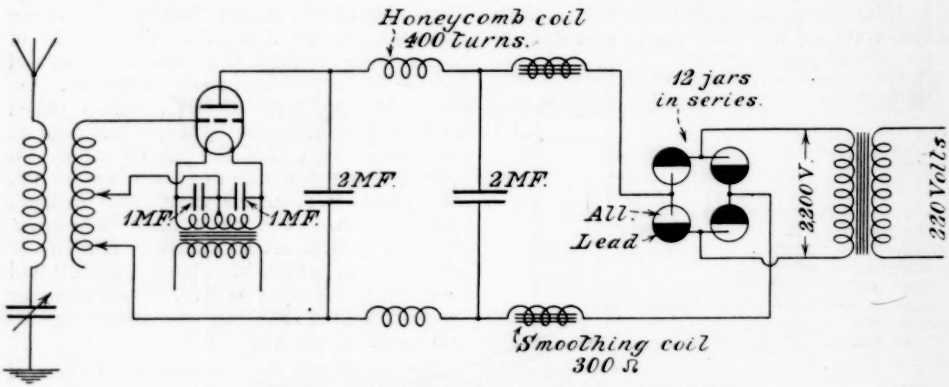


Fig. 4.—A modified form of Fig. 2 in which the supply is chemically rectified.

The primary coil of this circuit had twenty-four turns, while the secondary coil had forty turns litz wire wound on a coil of 8 cm. size. The strength of the signals with this circuit was very good, but tuning was difficult, as the aerial coupling had an influence on the oscillation of the valve.

secondary condenser is about 240 cm. This is of great importance for receiving very short wave-lengths.

With this receiver and one detector 0AR heard the following American amateurs on the morning of December 2 :—1BEP, 1XAM (on 100 metres very qsa), 2AWF, 8NB,

8CKN, 8CEI, 1CMP (calling French 8AB), 2RK (qsa), 1XM (on 100 metres very qsa), 2BD, 9VM and 9AN.

For transmission 0AR (a combination of three amateurs) used the following circuit (Fig. 3). The primary coil had 25 turns, wound on a coil of 12 cm. size. The grid-coil had 25 turns, wound on the same coil of 12 cm. size. The high tension used for the plate was full alternating current, without any rectifying. With three 10–20-watt valves ("Telefunken") an aerial current was obtained of 2·5 amps. on a wave of 210 metres.

The note was very bad because of the terrible "hum" of the alternating current, so that 0AR looked for a rectifying method. Some days before the trans-Atlantic tests the following corrections were made (Fig. 4): The primary coil and the grid-coil were changed into ebonite crosses, round which concentric hoop copper was wound. The two coils were fixed on hinges so that the exact coupling was easily found. The high tension of 1,500 volts was changed into 2,200 volts and rectified by an electrolytic rectifier (ammon. phosph. 10 per cent. solution), making use of the so-called "Grætsche circuit," to rectify the two phases of the alternative current.

Two high-frequency chokes were placed in the high-tension leads. The chokes were common honeycomb coils of 400 turns. By this the plate current decreased 50 milliamperes. Condensers of 1 mfd., placed across the two halfs of the filament turns, made the note clearer.

After these corrections an aerial current of 2 amps. was obtained on a wave-length of 130 metres.

The aerial used was 20 metres long, 16 metres above the roof by means of two wooden masts. Below the aerial is a counterpoise of six wires, 25 metres long, 2 metres above the roof.

Transmitter and Receiver of oDV.

Fig. 5 shows the old transmitter of 5 watts, with which the first results were obtained. The high-tension transformer is on the table in a tin-lined iron box, filled with oil. Against the wall we see the unmounted 5-watt valve, the transmitting spider-web coils, and filament-plate and aerial-current ammeter. Near the transformer is the high-tension condenser of 2 mfd. The transmitter is visible mounted, as shown in the photo. All parts were made by himself, except the valves and ammeters. The antenna was a cage-aerial, 30 metres long and 16 metres high. A counterpoise was used of five wires and 50 metres long, which was used together with the common water-pipe earth.

Some days before the beginning of the tests the transmitter was fitted out with

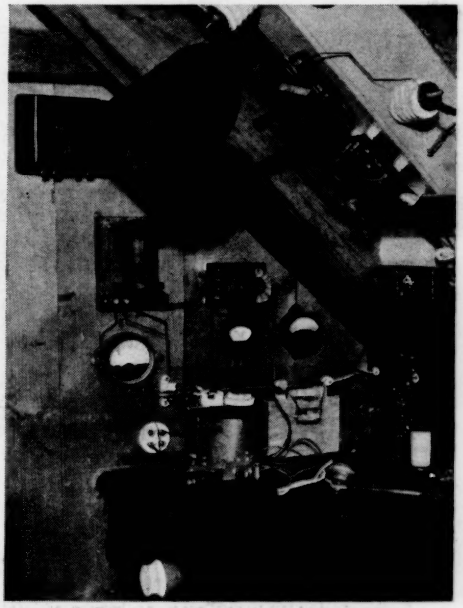


Fig. 5.—The original transmitter at oDV.

two 10–20-watt valves, and a new high-tension transformer was built.

To get a shorter way of his aerial to his transmitter the whole transmitter was removed to another corner of the room and was mounted there in haste, because it was one day before the tests (Fig. 6). To get the 100-metre wave the aerial must be shortened to a length of 12 metres and the counterpoise kept at a length of 50 metres. Especially the shortening of the aerial was accompanied with great trouble, in a very severe frost and snowstorm, during the A.R.R.L. days.

Fig. 6 shows the transmitter with which oDV bridged the ocean. To the right of

the photo, mounted against a chimney, is a ring-transformer, primary 220 volts, secondary 12 volts 10 amps. for filament of the transmitting valves and 2 volts 15 amps. for filament of a neon gas-rectifier valve. This valve is visible below the ring-transformer, and can be used for two-way rectifying, maximum 3,000 volts and 300 milliamps. Owing to this valve being so very short-lived (25 hours), oDV only used this neon valve for long-distance work.

Above the table we see the transmission coils and the filament ammeter, and on the table the two transmitting valves and a "Philips" rectifier valve of 100 milliamps.

Fig. 7 gives the transmitting circuit of oDV. The coils have been wound concentrically. Coil 1 has six turns and coil 2 has eight turns, both of 2·5 mm. wire size; coil 3 has twelve turns, wire size 1 mm. The capacity across coil 2 is about 0·0002 mfd. During the tests a radiation was

Fig. 6.—The rearranged transmitter at oDV which resulted in a much shorter aerial lead.

Below the neon valve is the "power switch," which varied the number of turns of the filament transformer in series with the high-tension transformer. This high-tension transformer is not visible in this photo, and is hung up in a wardrobe to deaden the buzzing of the transformer when it works with its full power. This transformer gives 2×2,300 volts, and is wound in segments, with wire of 0·3 mm. size. Below the "power switch" is a smoothing coil with a 2 mfd. high-tension condenser. Look at the other smoothing-coil, mounted in an old chocolate box and hanging up free above the floor!

obtained of 1·5–2 amps. on 110–130 metres, with an input of 200 watts. After some nights of testing oDV had the good fortune to be reported by 1KW.

In the beginning oDV had some hard luck with his high-tension condensers, and lost three of them. Being afraid that he would also lose his last one he decreased his high tension to 1,800 volts. Antenna current was then 1·4 amps. Also with this decreased power oDV was reported on other nights.

For receiving the circuit shown in Fig. 8 was used, with a reaction circuit like the "Reinartz."

The primary, secondary and reaction coils

are wound like spider-web coils, and are built in the set. The regulating of these coils is done at the side of the set. The primary coil has seven turns, secondary coil ten turns, and reaction coil has fifteen turns for reception of 80–250 metre waves. A two-grid valve, "Siemens-Schottky," with 12-volt plate tension, was used. Most American amateurs and American broadcasting stations were very good on one valve.

Finally, some news about station oYS. The same transmission circuit was used as described already in the November issue of EXPERIMENTAL WIRELESS, Fig. 8.

With two 10–20-watt valves and a common water-pipe earth he had an aerial current of 1·4 amps., while using a counterpoise and the same transmitter an aerial current of 2·5 amps. was obtained.

The aerial of 24 metres was too long—the lowest wave was 140 metres—but there was

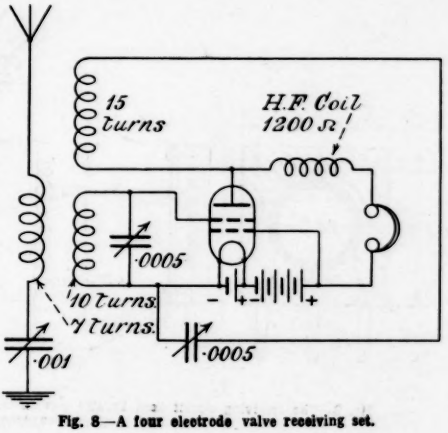


Fig. 8—A four electrode valve receiving set.

in the middle. No special manner was used to wind this inductance. The turns

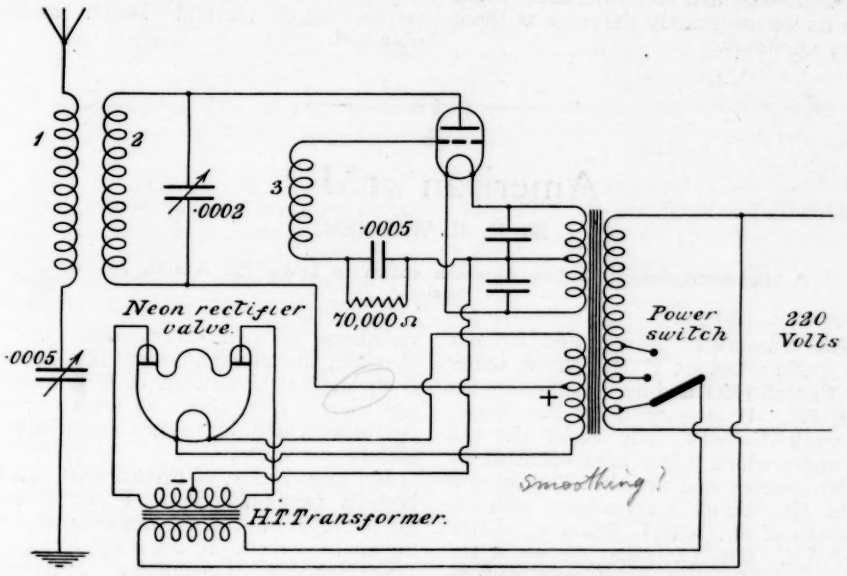


Fig. 7.—The supply to the anode at oDV was rectified by a special neon tube as shown above.

no time before the tests to shorten his aerial. Till this moment there has been no report as to whether oYS had any results with his testing.

For receiving a kind of "Reinartz" receiver was used (Fig. 9). The inductance is wound in one piece, with one tap about

are laid in a small hollow wooden plank, 60 × 65 mm. The hollow is covered by means of a second little plank.

For waves of 100–250 metres the best result was obtained when about eight turns were used for the part *a* and about fifteen turns for the part *b*.

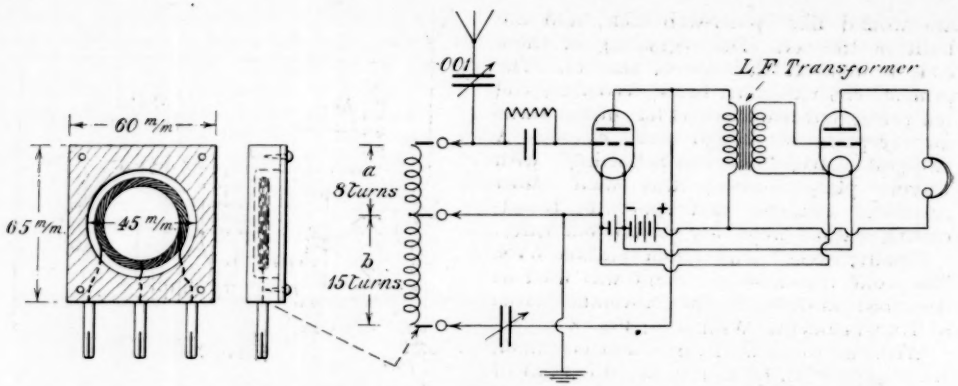


Fig. 9—The receiving circuit used by oYS was another modified form of Reinartz receiver with one stage of low frequency amplification.

As we see, most Dutch amateurs use their own transmission and receiving circuit, and seldom do we use exactly the same as those of other amateurs.

When we look back to the past days of testing we may be very content with the results which several Dutch amateurs obtained.

American 1MO.

By K. B. WARNER.

A brief description of the first American station to bridge the Atlantic on 100 metres.

THIS transmitter is operated by our traffic manager, F. H. Schnell, under the call 1MO, and by myself under the call 1BHW. It is licensed for the shorter wave work, however, only under the call 1MO, under which it has been operated by both Mr. Schnell and myself. The set was built by Mr. Schnell in accordance with the suggestions of Mr. John L. Reinartz, of 1QP and 1XAM. The particular virtue of the circuit lies in its ability to shift rapidly wavelengths, and yet maintain the node in a fixed position.

Briefly described, the circuit is a full-wave self-rectifying circuit, with two UV203A tubes on each half of the cycle. Whatever unusual merit it may possess as a transmitting arrangement probably lies in its ability to work well below the fundamental of the antenna, in the region where the radiation resistance is relatively enormous. For example, the antenna current on 200 metres is in the neighbourhood of 6 amperes, at 115 metres it is about 2¼ amperes; these figures with an input to the plates of approximately 400 watts.

Mr. Leon Deloy, of French 8AB, has long been a personal friend of Mr. Schnell's. Deloy was in this country this summer, studying amateur methods, and decided to employ this Reinartz transmitting arrangement. Returning home, he installed it, and upon completion wired the traffic manager that he would start transmitting on the Sunday night before Thanksgiving. Schnell hurriedly wound a few coils for a crudely made short wave receiver of the tickler feedback type, and was listening on 100 metres at the appointed time. Deloy was received quite splendidly—with two-step audio amplifier

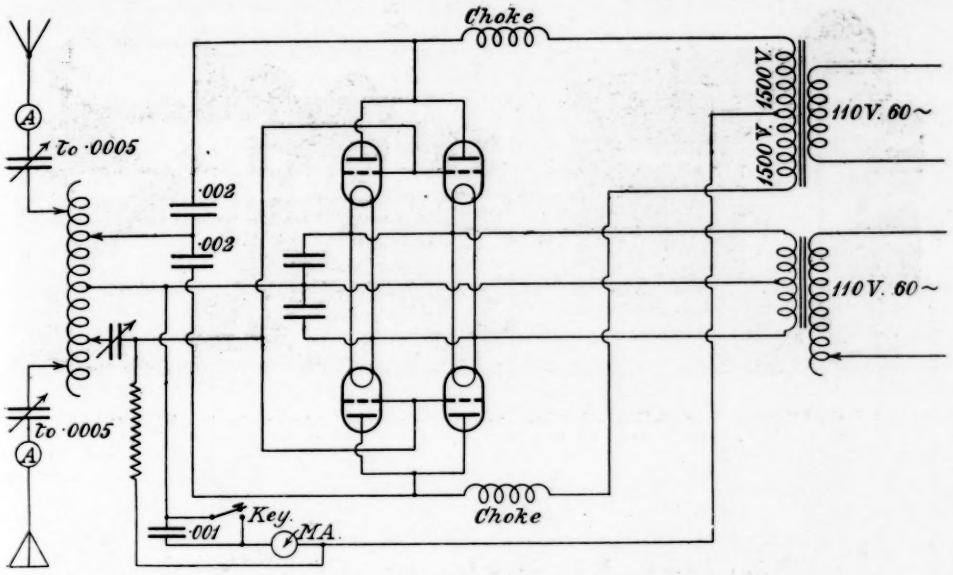


Fig. 1.—The circuit used at 1MO is a full-wave self-rectifying circuit employing UV203A valves in parallel.

his signals could be heard 25 feet from a phonograph horn carrying an ordinary telephone. His broadcasts were copied on the nights of November 25 and 26. By the night of November 27 Mr. Schnell had secured permission from the Radio Supervisor to use the wave-length of 115 metres, and upon the conclusion of Deloy's broadcast that night he called him and communication was established. Since then it has been accepted as a matter of course. Deloy is worked almost every night, and probably a dozen American stations have connected with him. His signals have been heard far inland, and with very good audibility. On the night of December 7, at the conclusion of our regular schedule with French 8AB, he assisted in connecting me with British 2KF, of London, whom I worked for a matter of several hours, stopping only at 8.40 British time when the signals of 2KF finally faded out here. I have worked 2KF a total of five times. On the night of December 11, at the conclusion of correspondence with him, he asked me to listen for British 2SH, our mutual friend Hogg, and I am happy to say that I connected up with him, too, for a period of about two hours and ten minutes. I had a schedule with him later in the week, but unfortunately

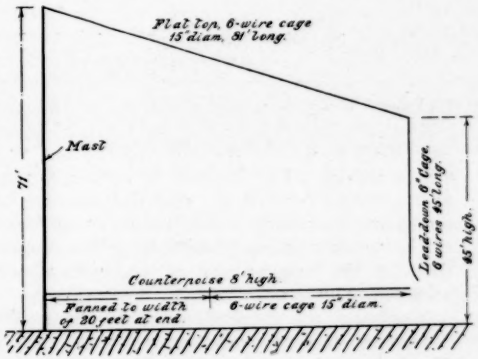


Fig. 2.—The aerial and counterpoise system at 1MO.

could not hear him. On the night of December 15, at the conclusion of correspondence with French 8AB, he connected me up with French 8BF, our fourth European correspondent, with whom I talked for over half an hour.

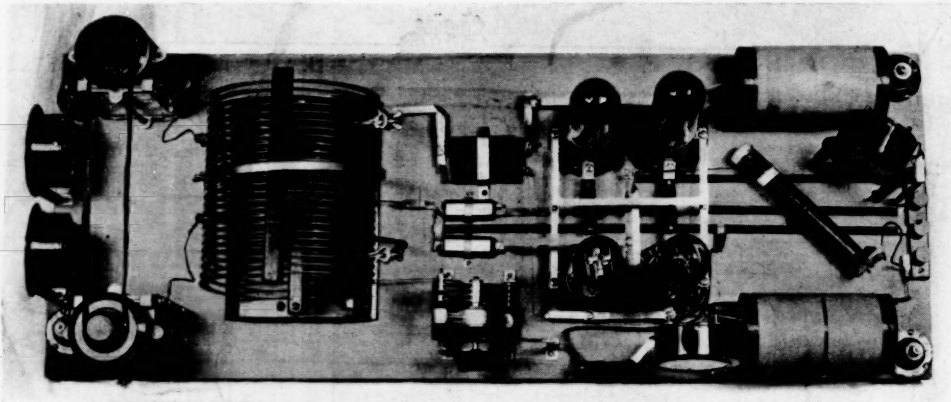


Fig. 3.—Showing the layout of the apparatus. Note the two condensers linked together by a belt so as to enable the aerial and counterpoise circuits to be adjusted simultaneously.

Modern Methods of Production.

SOME IMPRESSIONS OF THE STERLING WORKS.

IT was with very great interest that we accepted the invitation of Mr. Guy Burney, Managing Director of the Sterling Telephone & Electric Co., Ltd., to visit their extensive works at Dagenham, where we were able to obtain some insight into modern methods of mass production. Apart from technical points, we could not help being impressed by the elaborate and splendid organisation which prevails throughout the whole works. The factory is certainly run under model conditions, and the amount of consideration which is devoted to the welfare of the workers is, no doubt, largely responsible for the atmosphere of goodwill which seemed to prevail wherever we went.

Statistics are of little use in giving the reader an accurate impression of the size of the factory, but some idea of its extent can be obtained from the fact that the power house comprises six 200-kilowatt units. These, it may be mentioned, are driven by Browett-Lindley gas engines, which derive their power from a suction gas producer system installed nearby. We were told that the fourteen hundred kilowatts which are available are scarcely sufficient to maintain the whole works in operation. It is interesting to note that although alternating current is becoming almost universal, in this instance direct current is used on account of its greater flexibility for purposes for which it is required.

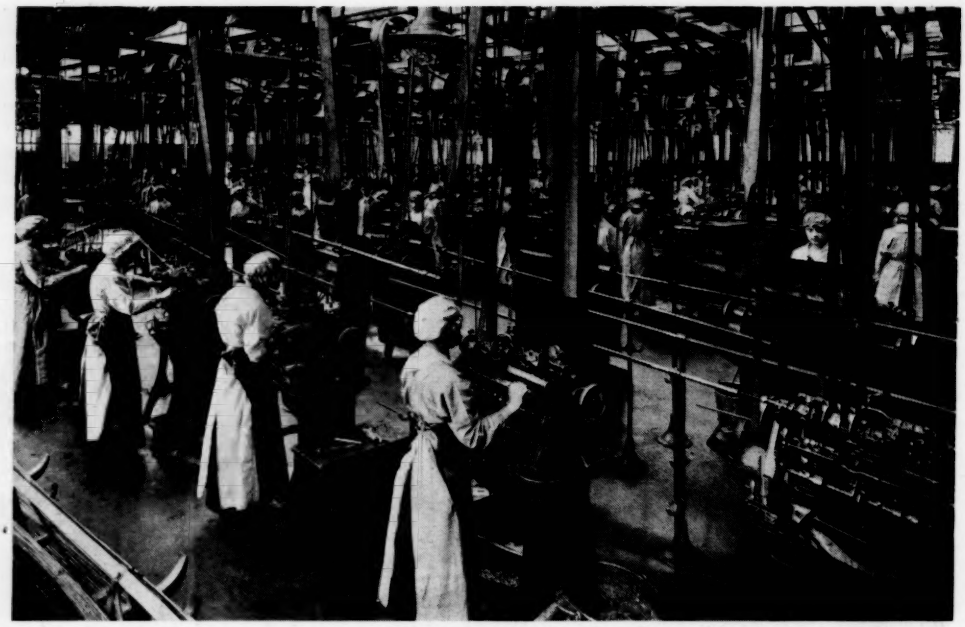
It will, no doubt, be remembered that the greater portion of the Sterling Works is devoted to the manufacture of Post Office telephone apparatus and wireless receiving gear, which necessitates the use of wooden cabinets. This great demand for cabinet work has brought into existence a special department, and perhaps the methods employed will be of some interest to our readers. Until recently there had been considerable difficulty in securing the large amount of really well-seasoned timber which has been necessary. However, this difficulty has been overcome by the installation of what we may best term a seasoning plant. A series of drying kilns are used, in which the timber is placed for some three weeks under accurate temperature and humidity control. The timber is then removed and it is accurately analysed for moisture content, and having passed the test satisfactorily, it is then ready to be sent to the cabinet shops. The cabinet

shops themselves are very completely equipped with very up-to-date machinery, great use being made of sand-papering machines. The sand-papering machine, we understand, is extremely economical in working, and, moreover, gives an extremely fine surface to the wood. It is particularly interesting to note that all the driving machinery is concealed in tunnelling under the floor, several machines being grouped together and driven by one electric motor. We were told that considerable difficulty was experienced when the system was installed, owing to the fact that the proximity of the works to the river resulted in standing water being very near the surface of the ground. This necessitated the construction of special channels for the driving machinery, and we were told that they were formed of puddled clay, heavy concrete, asphalte, brickwork and cement. The atmosphere of a cabinet shop is usually associated with vast quantities of sawdust, shavings, etc., but in this instance none was present owing to the fact that a very elaborate system of suction ventilation is employed.

The methods used in finishing the wood are equally as ingenious as those used in working it. Unfortunately, we are not at liberty to give any details of the methods used, but we may go so far as to say that they are entirely different from those usually adopted in polishing. The wood is first treated with a special filler, and is subsequently mechanically coated with a special varnish which can either be made to have a high polish, or, alternatively, a streaky dull appearance of wax-polished timber. The advantage of this method results in a saving in time, a lower cost of production, and a finish to the wood which is quite waterproof, a feature which should be of great advantage in electrical apparatus.

Some idea of the extent of the Sterling works can be gathered from this view of their own tool shop.

Usually the assembly of finished cabinet work and the fitting of the instruments needs considerable care and adjustment, but Mr. Max Lawrence, the distinguished works manager, who accompanied us throughout out tour of inspection, informed us that the cabinet work has been standardised so successfully



A busy corner of a machine shop. Note the battery of automatics in the foreground.

and the timber so accurately seasoned, that everything is always in perfect register.

Roughly speaking, the output of the Sterling Works can be divided into two classes—telephone apparatus, which is under the charge of Mr. F. R. Griffiths, and broadcasting apparatus which has been designed entirely by Mr. D. Ward Miller, who, no doubt, is well known to many of our readers. The instruments are made so many and various that in the short space available it is quite impossible to deal with each adequately, and, therefore, we cannot do better than generalise, dealing more fully with points of special interest. Perhaps one of the most interesting departments is that in which the well-known Sterling high-resistance telephones are wound. Special precautions are taken to protect the telephones from all injurious influences, especially from the effects of damp, and this is no easy task in view of the fact that some 20,000 turns of wire are used in each pair of telephones, which, of course, means that an exceedingly fine gauge has to be employed. The wire, as a matter of fact, is enamelled copper of about 1-1,000th inch in diameter. Transformer coils receive equal care, and before they are wound the reels of silk-covered wire are impregnated *in vacuo* with hot paraffin wax, which results in a coil of greater mechanical and electrical strength. Reverting to the subject of telephones, we were particularly interested in the production of the magnets, great care being taken to bring the high-quality tungsten steel into the best electrical and mechanical condition. The distance between the diaphragm and the magnet is of considerable importance, and when the magnets have been assembled within the cases, the receiver is placed on a machine, which grinds down the magnet poles until they are of exactly the correct length. The manufacture of loud speakers is another process worthy of mention. The movement of the loud speaker, of course, is very similar to that employed in the ordinary headphone, but the horn embodies several interesting features. The flare is spun out of aluminium in the usual way, but the throat is made of two brass pressings brazed together at the edges. The join is subsequently examined to ensure that

it is faultless. The throat is then tin-plated before it is passed to the finishing shops. No doubt many of our readers are familiar with the decorative Sterling loud speakers. The finish is secured by means of stencils and air brushes, and although the process may appear as being almost mechanical, it undoubtedly depends very largely upon the artistic individuality of the operator. Here, again, the enamels, etc., are of a special type, and are worked in a somewhat similar manner to the varnishes used in the cabinet shops.

Sterling broadcast receivers are too well known to call for comment, but it is interesting to note that the complete receiver is made in the form of a unit which slides into the cabinet. The black-finished brass front panels are certainly novel, and have many points in their favour. In addition to elaborate testing, each instrument is examined on broadcast signals before being finally passed.

To the mechanical engineer, no doubt, the most interesting section of the works would be the gigantic main machine shop, which is literally crammed with automatics, and a tremendous amount of turret work is done here. The other section of the building is devoted to press work, which plays no small part in the Sterling productions. It is a matter of some regret that we are not at liberty to make known to our readers some of the most interesting points in the production of Sterling apparatus, but we can assure them that a higher standard of workmanship and quality would be hard to find, and we are very greatly indebted to Mr. Guy Burney for the opportunity he has afforded us for examining modern methods of production.

One of the cabinet shops in which the artificial ventilation installation is clearly visible.

The Trend of Invention.

We summarise below the more important wireless inventions which have been disclosed during the month, special reference being made to those of immediate interest to the experimenter.

Microphone Design.

New types or designs of microphone are always of interest—especially to the radio man who has at heart the improvement of radio-telephony. Fig. 1 shows a recently patented mode of construction for carbon

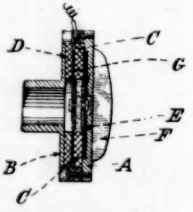


Fig. 1.—A new type of carbon microphone.

granule microphones, which rather appeals to us. The chief object of this invention is to support the moving diaphragm entirely by felt, or similar substance, and avoid rigid contact with the metallic case, thus making the microphone practically aperiodic in response, and avoiding the resonance which is so predominant in most commercial microphones. Fixed to the back A of the case is a metallic disc E, faced with the usual carbon disc, which forms the back electrode of the granule chamber. In front of this disc is a disc C of felt with a hole cut in its middle to form the granule chamber. Placed in front of this felt disc so as to close the granule chamber is the diaphragm G, which is held in position by the felt disc C and a second similar felt disc D. Thus, when the front plate B of the microphone is screwed in position sufficient pressure is exerted to hold the diaphragm securely in place. The inventor prefers to cut the hole in the felt discs to an oblong or elliptical shape, with the major axis horizontal. The diaphragm itself is of such a thickness that it moves as a whole and not only at its centre. Connection is made to the diaphragm by a thin strip of metal. The back of the case is provided with radiation fins so that the microphone may be used with comparatively large currents for prolonged periods without undue overheating. (British Patent 209,173, E. A. GRAHAM).

High-Speed Morse Recorder.

Fig. 2 illustrates British Patent No. 190,113 (Marconi's W.T. Co., Ltd.), the chief point of interest in this invention being the means whereby small currents directly control the movements of the marking stylus. A polarising winding C is energised by a local source of current, the case A, the core B, and top plate E all being made of iron, and forming a magnetic circuit which is closed except for a small annular air gap round the top of the central core B. An intense magnetic field is thus formed in the annular air gap, and in it is suspended a light ring-shaped coil of fine insulated wire, shown in section at D. This coil may contain 500 to 1,000 turns of wire, and is suspended from the light aluminium arm F, which is capable of oscillation in a vertical plane, and whose free extremity carries an inking stylus which makes the

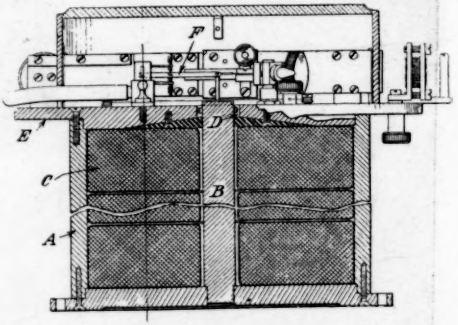


Fig. 2.—A high-speed Morse recorder working on a principle somewhat similar to that of the "Magnavox" loud speaker.

record on the moving tape. Signalling currents are fed into the suspended coil D, and, owing to the strength of the polarising field, quite small currents in D will result in a strong solenoidal force which actuates the recording arm F. The principle on which the electro-magnetic system of this invention acts appears to be identical with that used in the

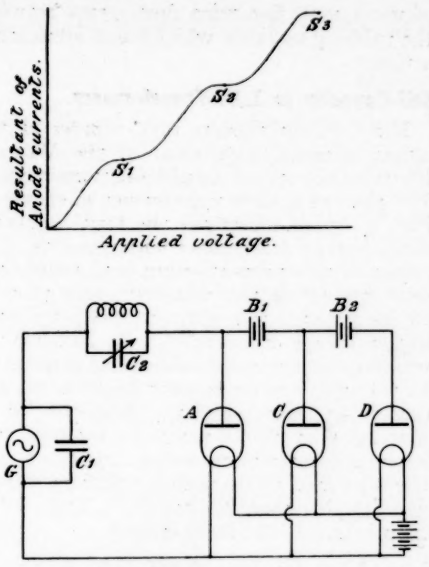


Fig. 3.—Another circuit for frequency multiplication.

Magnavox loud speaker, the only novelty lying in its application to Morse recording. Full details of mechanical construction, which we cannot reproduce here, are given in the specification referred to.

Valves as Frequency Multipliers.

Most static devices for raising the frequency of an A.C. source depend on using some saturation or threshold effects to distort a sine wave in such a way as to be resolvable into some multiple frequency or frequencies. The most practicable devices hitherto devised have depended upon the magnetic saturation of iron or its alloys. British Patent 208,735 (J. Scott-Taggart and Radio Communication Co., Ltd.) suggests a method of utilising the properties of thermionic valves for frequency multiplication, or effecting any desired change in wave-form. Fig. 3 illustrates the broad idea of the invention simply. In series with the source G are a number of two-electrode valves A, C and D (and more if wanted) in multiple connection across G. By means of batteries B_1 and B_2, the anodes of C and D are given suitable negative biases, so that the anode of C is more negative than that of A, and that of D is more negative than that of C. Now consider what may happen when the positive half-cycle of e.m.f. is generated by G. A will at once begin to conduct, but C and D will not, owing to their negative biases. The current through A will increase until saturation current is reached; there will then be no further rise in current until the positive e.m.f. of the source G has risen sufficiently to overcome the back e.m.f. of the battery B. When this happens C will begin to conduct until it is saturated, and again a further increase of current will be delayed until the back e.m.f. of B_2 is overcome. The curve in Fig. 3 shows the state of affairs in the first part of the positive half-cycle, the same things happening in the reverse order in the second part of the positive half-cycle (not shown). The result of so distorting the positive half-cycle is the production of a strong harmonic component, which may be selected by a circuit LC_2 included in series with the source G, and tuned to the said harmonic frequency.

The specification describes modifications of the invention, including the extension of the idea to three-electrode valves, in which latter case the grids are successively biassed and the harmonic frequency is delivered in the common anode circuit.

Ingenious as this invention is, it has a serious fallacy, which will, no doubt, occur to

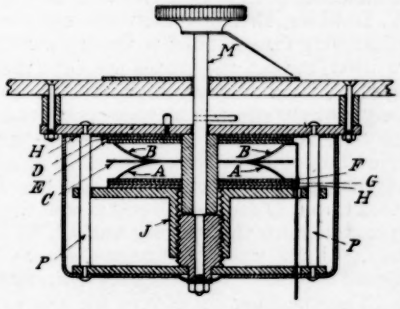


Fig. 4.—A variable condenser of the well-known "Polar" type.

some of our readers, namely, that since thermionic valves only conduct one way, the devices will only act on the positive half-cycles, there being no output on the negative halves. Hence the output will be completely interrupted each cycle for a period lasting half a cycle—resulting in the production of an infinite series of harmonics.

Variable Condensers.

Fig. 4 illustrates the construction of a condenser of the type of the now familiar "Polar." The condenser plates, of which there are only two, consist of sheets D and G of copper foil mounted on sheets of press-pahn, or similar resilient material, marked

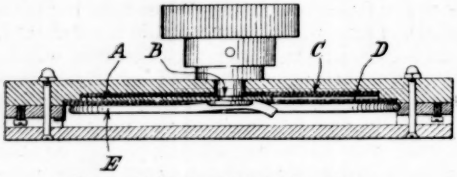


Fig. 5.—A "mica lubricated" condenser.

H. Sheets of mica E and F prevent the plates being short-circuited. The condenser plates are always kept parallel and are urged apart by means of tongues A and B, bent out from the springy metal sheet AB. By rotating the knob attached to the spindle M the support J of the lower plate is urged towards or away from the upper one by virtue of the screw-thread in J. The guide bars P prevent J from rotating. (British Patent 208,598, F. K. Crowther and Radio Communication Co., Ltd.)

Another method of making a compact variable condenser is illustrated in Fig. 5. (W. Dubilier, British Patent 201,138.) Fixed and moving vanes similar to the ordinary type are used, but all the plates are kept pressed together, the necessary dielectric separation being entirely effected by thin sheets of mica. The moving vane A is a brass semi-circular vane about four or five mils thick, and connected rigidly to the spindle B. The fixed vanes C and D are also of metal foil, and are separated from the moving vane A by mica discs. All the vanes and mica discs are kept pressed together by the spring wire retainer E. The specification covers the use of this arrangement with a plurality of moving vanes as well as only one as illustrated. It is stated that owing to the small co-efficient of friction of a mica surface that the arrangement works better than similar types of condensers employing hard rubber or ebonite dielectric. Apparently after a certain amount of use a very fine mica dust forms between the rubbing surfaces which has a lubricating action.

Self-Capacity in L.F. Transformers.

Many of our readers may wonder at the rather unusual dimensions of the Western Electric Co.'s speech amplifying transformers. The plan of such a transformer is shown in Fig. 6, which illustrates the large diameter of the bobbin A compared with its width. The object of this proportioning is to reduce the self-capacity of the windings, and thereby to increase the transformer efficiency on the higher speech frequencies. By making the windings on a narrow bobbin and making up for the otherwise consequent loss of accommodation by increasing the diameter, it is obvious that the separation between the inner and outer turns will be increased, and the self-capacity decreased. (British Patent 209,345, Western Electric Co., Ltd., C. P. Smith, and W. L. McPherson.)

Iron Alloy for Iron Cored H.F. Circuits.

In the early days of radio it was thought that it would not be practicable to use iron-cored coils for H.F. work owing to the high hysteresis and eddy-current losses—especially the latter. Later it was found that a reasonable efficiency could be obtained provided that the iron was very well laminated, and suitable insulation effected between the laminations. Also the eddy currents can be minimised by using iron alloys of high resistivity, and such alloys should also have a low hysteresis loss. The composition of an

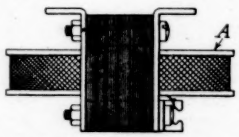


Fig. 6.—The bobbin of the Western Electric Transformer is of the shape shown above in order to decrease the self-capacity.

alloy to meet these requirements has recently been patented by Marius Latour (British Patent 209,683). This alloy contains 33 to 39 per cent. of nickel, and 0·5 to 1 per cent. of manganese.

Loud Speakers and the Institution of Electrical Engineers.

In our issue of January last we published abstracts of two of the papers read on November 29, 1923, at the Institution of Electrical Engineers, the occasion being a joint meeting with the Physical Society of London. The meeting remarkably demonstrated the great interest taken in the subject of, and the large amount of experimental work which has been and is being done in connection with "loud speakers," and the scope this part of wireless apparatus alone offers to experimenters. So large was the attendance that the lecture theatre was crowded to the doors, many members went away having been unable to obtain admittance. Dr. Eccles, speaking in the discussion, remarked that the "loud speaker" had brought about a new era in which one man can address thousands. One of the difficulties in evolving a loud speaker was that it must be able to cope with a wide range of vibrations. An audience came either because they were interested in or liked music, because they wanted to hear broadcasting, or because they were scientifically interested. Referring to the experiments and success obtained by the Western Electric Laboratories, he said if you are near the loud speaker the sound seems too loud, if far away it is too faint for ordinary conversation, if you are at the right distance you would say it was the actual voice of the speaker. Oscillograph curves taken from a gramophone speaker indicated the difficulties. He estimated loud speaker efficiency as only one tenth of one per cent. The discussion, as a whole, indicated that there are great difficulties in the way of evolving a loud speaker which will serve perfectly under all conditions. Acoustics enter largely into the matter, the size and the sound conditions of the place in which a given loud speaker may be used. An instrument which gives satisfactory results in a large hall may be unsatisfactory in a room or even in another hall. One remark was to the effect that horns for use in small rooms should be short rather than long. Makers of gramophones have had to deal with similar difficulties. A variety of demonstrations with loud speakers was given during the evening. Mr. Sandeman had made experiments, and showed curves demonstrating the effects of filtering out frequencies below 1,500 and above 1,500, and of admitting both; they indicated that distortion occurred with frequencies above or below 1,500. Professor MacGregor Morris gave a very interesting demonstration of his experiments to discover overtones in the diaphragm of a telephone receiver. They are based upon Chladni's experiments in which sand placed upon a metal plate distributes into lines and curves depending upon the vibrations imparted to the plate. The discussion was resumed on February 14. It demonstrated further that loud speakers are a very complex problem, not only affected by design of apparatus, but having to meet actual defects of sound reception in the human ear itself. Mr. A. J. Aldridge showed some curves illustrating comparative output and input of a diaphragm with a given input of energy. There were more demonstrations with apparatus, one being with two loud speakers, the horn of one delivering into the horn of the other. Apparently the resonance of the horn itself is of small consequence, because the horn magnifies so greatly the happenings which occur in the apparatus connected to it. Mr. Burnand described experiments he had made with two loud speakers in series. Sometimes one and sometimes the other appeared to take charge of the sound delivery. He suggests two horns combined, and humorously remarked that there is a great opportunity for an experimenter to be shut up in a room with a plentiful supply of horns and paraffin wax. This remark amused the audience; also his further observation that he had personally worked out about 9,000 windings. The position was tersely summed up by another member in the following observation:—"The weakest link in broadcasting is the receiver, and the weakest link in the receiver is the loud speaker." From our point of view the papers and discussion are an object lesson to experimenters, showing that useful and important work can be done by devoting attention to a single detail where improvement and development may be needed.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in the early issues of "Experimental Wireless."

I.—TRANSMISSION.

UNE ANTENNE D'EMISSION POUR AMATEURS.—P. Bouvier (*R. Elec.*, 5, 52).

UBER DIE ABHÄNGIGKEIT DER FREQUENZ DES RÖHRENSENDERS VON DER HEIZUNG DER RÖHRE UND DER ANODENSPANNUNG.—Felix Strecker. (*Jahrb. d. drahtl. Tel.*, 22, 6).

THE D.C. VOLTAGE RAISER.—Marcus G. Scroggie, B.Sc. (*Exp. W.*, 1, 5).

THE IMPROVED "S" TUBE RECTIFIER.—James L. Jenks, Jr. (*Q.S.T.*, 7, 7).

SOME CHARACTERISTICS OF ELECTROLYTIC RECTIFIERS.—E. J. Atkinson (*Q.S.T.*, 7, 7).

II.—RECEPTION.

LOUD SPEAKERS.—E. K. Sandeman (*W. World*, 232 and 233).

ELECTROLYTIC DETECTORS AND LIQUID VALVES.—James Strachan (*W. World*, 232).

A FOUR-VALVE DUAL NEUTRODYNE RECEIVER.—W. James (*W. World*, 233 and 234).

LE MEILLEUR RÉCEPTEUR POUR TOUTES LONGEURS D'ONDE (80 À 25,000 MÈTRES).—J. Reyt (*R. Elec.*, 5, 53).

MESURE DE LA PUISSANCE DE RÉCEPTION.—J. Roussel (*R. Elec.*, 5, 53).

DESIGN FOR A DUO-REGENERATIVE RECEIVER.—Capt. St. Clair-Finlay, B.Sc. (*Exp. W.*, 1, 5).

LOW LOSS TUNERS.—S. Kruse (*Q.S.T.*, 7, 7).

A NEW TYPE OF R.F. TRANSFORMER.—S. Kruse (*Q.S.T.*, 1, 5).

III.—MEASUREMENT AND CALIBRATION.

DIE EINFUNKENMETHODE FÜR MESSUNGEN MIT KONDENSATORSCHWINGUNGEN. — O. Meisser. (*Jahrb. d. drahtl. Tel.*, 22, 5).

DEKREMENTBESTIMMUNG, BESONDERS VON STARK GEDÄMPFTEN KREISEN MITTELS STOSSERREGUNG UND EINFUNKENMETHODE.—O. Meisser. (*Jahrb. d. drahtl. Tel.*, 22, 5).

PIEZOELECTRIC CRYSTAL RESONATORS AND CRYSTAL OSCILLATORS APPLIED TO THE PRECISION CALIBRATION OF WAVE-METERS.—George W. Pierce (*Proc. Amer. Acad. Arts and Sci.*, 59, 4).

IV.—THEORY AND CALCULATION.

SOME NOTES ON CALCULATING THE INDUCTANCE OF COILS.—E. J. Hobbs (*W. World*, 233).

CALCULATIONS OF CAPACITY.—E. J. Hobbs (*W. World*, 234).

WIRELESS TELEGRAPH THEORY.—Alfred A. Robb, Sc.D., F.R.S. (*Electn.*, 2386).

V.—GENERAL.

DESIGN OF LOOP ANTENNA.—Ralph Butcher (*W. Age*, 11, 5).

K.D.K.A. EXPERIMENTAL WORK ON THE RELAYING OF AMERICAN BROADCASTING.—W. J. Brown, B.Sc. (*W. World*, 235).

LOW CAPACITY INDUCTANCE COILS.—H. F. Haynes (*W. World*, 235).

HOW TO DESIGN INDUCTANCE COILS.—Samuel C. Miller (*W. Age*, 11, 5).

A PROPOS DE LA CAPACITÉ DES CONDENSATEURS.—Michel Adam (*R. Elec.*, 5, 52).

LA PROPAGATION DES ONDES ET LES INSECTES.—F. Marre (*R. Elec.*, 5, 53).

UBER AUSBREITUNGSVORGÄNGE UND EMPFANGSSTÖRUNGEN IN DER FUNKENTELEGRAPHIE.—F. Kiebitz (*Jahrb. d. drahtl. Tel.*, 22, 5).

OSCILLOGRAPHE CATHODIQUE POUR L'ÉTUDE DES BASSES, MOYENNES ET HAUTES FRÉQUENCES.—A. Dufour (*L'Onde Electrique*, 11, 12, and 13).

DIE STEUERUNG VON HOCHFREQUENZSTRÖMEN DURCH EISENDROSSELN MIT ÜBERLAGERTER MAGNETISIERUNG.—L. Pungs. (*Elektrot. Zeitschr.*, 1923).

HIGH VOLTAGE PHENOMENA.—F. W. Peek (*J. Frank. Inst.*, 197, 1).

UBER DIE GÜLTIGKEIT DES OHMSCHEN GESETZES FÜR ELEKTROLYTE BEI SEHR HÖHEN FELDSTÄRKEN —Max Wien (*Ann. d. Physik*, 1924, 3-4).

POST OFFICE RADIO STATION, DEVIZES.—J. H. Reyner, B.Sc. (*Exp. W.*, 1, 5).

DIRECTIVE RADIO TELEGRAPHY AND TELEPHONY.—R. L. Smith-Rose, Ph.D., M.Sc. (*Exp. W.*, 1, 5).

VALVE MANUFACTURE: SOME GERMAN METHODS.—Dr. A. Neuburger (*Exp. W.*, 1, 5).

ELECTRICAL IMPULSES.—Dr. N. W. McLachlan (*Exp. W.*, 1, 5).

THE MAKING OF PURE SHELLAC VARNISHES.—J. F. Corrigan, M.Sc. (*Exp. W.*, 1, 5).

AMATEUR WAVEMETERS.—S. Kruse (*Q.S.T.*, 7, 7).

LOADED AERIALS.—P. K. Turner (*W. Trader*, 1, 12).

Correspondence.

To the Editor of EXPERIMENTAL WIRELESS.

SIR,—I notice that in his "Month's DX" for the February issue of this journal Mr. Ryan states that, as far as he is aware, the Swiss station XY has not been heard in this country yet. It may be of interest to know that signals were exchanged between XY and my own station as far back as March 12, 1923. I was listening in on about 200 metres on this date early in the evening, just after sunset, when I heard a faint C.W. station with an A.C. ripple cq-ing its heart out and sending the call XY. I immediately called him on C.W. with about 0·5 amp. in my aerial, and was promptly answered by him. Owing to qrm and qss we lost each other after a bit and never got in touch again.

The owner of XY, M. R. Luthi, sent me a card confirming the exchange of signals, stating that he was using two 5-watt valves and putting 0·4 amp. into his aerial.

My own reception was done on two valves, one H.F. and a detector.

Four hundred miles is quite a good distance for two-way working with only about 10 watts at each end, and I do not expect to repeat the test for many moons.

It is interesting to note that the arc station at Lyons does for M. Luthi what Northolt and Leafield do for us, inasmuch as the harmonics of YN produce "brouillage" on 200 metres, which, in the case of the communication mentioned above, was the factor limiting M. Luthi's ability to receive my signals. Evidently arcs will be arcs all the world over, and I am sure we will extend our sympathies to XY and other experimental stations similarly situated.

E. H. ROBINSON (2VW).

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—With reference to the letter by Mr. Voss in the last issue of EXPERIMENTAL WIRELESS, and to my previous letter, I should like to make a few remarks. I must plead guilty to overlooking the point noted by Mr. Voss, *i.e.*, that the formula takes into account the actual height of the aerial. However, another, and, if anything, more important, point has been overlooked. All these

formulæ which we have about aerials, etc., are worked out for an aerial excited at its base; that is, in this case the value for the resistance is given for the point at which the aerial is excited—at the base. Now the resistance of an aerial increases from the base to the free end, and in about 99 out of 100 cases in amateur stations the aerial is excited very considerably nearer its centre. In the case under discussion the aerial is excited at its centre, and is badly screened, the result being that the radiation resistance is apparently the same as if it were excited at the base, because the two conditions happen to cancel more or less: for objects in the immediate field of an antenna reduce its radiation resistance.

Unfortunately there was a rather serious misprint in my previous letter. The last sentence should have read: "and only serve as a very *rough* guide." It seems that we need something far better than the present formulæ before we attempt to apply them at all rigidly.

With regard to the thick wire question, I should like to bring out another point. Certain experimenters have tested coils wound with varying gauges of wire to the same pitch. They found an increase in efficiency as the size of wire was reduced up to a point, after which the results fell off again. Now a contingent point is the reduction in self-capacity due to the spacing of the turns. What is happening is that the eddy current losses and apparent resistance due to self-capacity are being reduced, but the true H.F. resistance of the wire is increasing as the size of wire is reduced. This naturally leads one to say that there is an optimum gauge of wire for a coil and optimum spacing for a definite frequency. A few calculations lead me to say that, in the case of a fairly large diameter single-layer coil, the optimum wire size and spacing are round about 20–22 S.W.G. and $\frac{1}{8}$ in. This has been confirmed by practice here, but a very great many more calculations must be made before the matter can be settled. Possibly someone who wants a job will tackle it!—Yours faithfully,

37, Bishop's Road, N.6. FREDERIC L. HOGG.
February 12, 1924.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—There are one or two points in connection with Mr. Voss's letter in the February issue of EXPERIMENTAL WIRELESS to which I should like to reply.

First, a minor point—he quotes the case where the local oscillations are smaller than the incoming signal, and refers to the extra selectivity obtained by a limiting action. If he will read my letter again, he will see I refer to that, and readily admit it.

Secondly, if Mr. Voss could give me an explanation of "grid condenser and leak" rectification without reference to the curvature of the grid-current—grid-volts curve I should indeed be grateful, as I cannot conceive of how a valve used in this way could possibly rectify on a linear grid characteristic.

Now with regard to the original problem, it seems to me that it is no use continuing to argue on the lines of purely physical explanation, as this does not take into account what is happening inside the valve, and is, in any case, somewhat unsatisfactory owing to its obvious lack of precision.

Let us consider the case where two E.M.F.'s are applied to the grid of the rectifying valve, "a. sin pt," due to the signal and "b. sin qt" due to the local oscillator. The resulting E.M.F. (v) is then given by:

$$v = a.\sin pt + b.\sin qt \quad \ldots\ldots(1)$$

And this will be a sine wave of frequency $\frac{p+q}{2}$ and of amplitude varying between $(a+b)$ and $(a-b)$.

If $a > b$ the beat amplitude will then be $2b$, which is a case we need not consider.

If $a = b$ *or* if $a < b$, the beat amplitude will be $2a$.

Thus, with $a = b$ we have the *maximum value of beat amplitude*, which, as Mr. Voss says, is what we want, but it is absurd to say that "it does not matter what proportion the rectified current bears to the unrectified." But the maximum value of beat amplitude is *also obtained if* $b > a$, so we must proceed to see what effect this has when it is applied to the rectifying valve.

The equation for the characteristic curve of a valve (whether it be the grid-current—grid-volts or the anode-current—grid-volts curve) can be expressed in the form of a power series:

$$I = A + Bv + Cv^2 + Dv^3 + \quad \ldots\ldots(2)$$

where I = anode current, v = volts applied to the grid, and A, B, C, etc., are constants depending on the construction of the valve.

Now the lower part of a characteristic curve very roughly follows a square law, so we might as a first approximation write (2) as follows:

$$I = A + Bv + Cv^2 \quad \ldots\ldots(3)$$

Substituting the value of "v" obtained from (1), we get:

$$I = A + B\,(a.\sin pt + b.\sin qt) + C\,(a^2\sin^2 pt + b^2.\sin^2 qt + 2ab\sin pt.\sin qt).$$

This may be written:

$$I = A + B\,(a.\sin pt + b.\sin qt) + a^2C\,(1-\cos 2pt) + b^2C\,(1-\cos 2qt) + 2abC\left[\frac{\cos(p+q)t}{2} + \frac{\cos(p-q)t}{2}\right]$$

In this expression the only term producing *audible* note in the phones is part of the last one, the actual value being:

$$acbC.\cos(p-q)t \quad \ldots\ldots(4)$$

Now by inspection of (4) it would appear that the greater the value of b, the greater would be the resultant note in the phones. This is not, however, strictly true, since we have assumed that the valve characteristic is satisfied by equation (3).

We cannot really get very near the true state of affairs unless we include another term from the power series, the equation then being:

$$I = A + Bv + Cv^2 + Dv^3 \quad \ldots\ldots(5)$$

The effect of the addition of this term is that there is an *optimum* value for b which is *greater than* "a."

The whole matter is dealt with at length, including experimental results, in a paper by Dr. E. V. Appleton, entitled "Optimum Heterodyne Reception," which should shortly appear in the *Proceedings* of the American Institute of Radio Engineers.

I cannot see how the case for equal amplitude of local oscillations and signal oscillations holds good under *any* conditions. (I am not considering the case of selectivity).

I have taken the simplest (though not strictly true) case, and it certainly does not hold there, and it does not hold for a four-term power series, as

pp 371-2 between 354-355

shown in Dr. Appleton's paper. So where does Mr. Voss get his theory from ?

Apart from the pure theory, E. H. Armstrong has shown with curves obtained from *experiments* that the telephone current gets greater as the amplitude of local oscillations is raised *above* that of the incoming signal (*Proc.*, I.R.E., Vol. 5, p. 145, 1917).

Speaking from memory, I think he shows that the value of the ratio of strength of telephone current when optimum heterodyne point is used, to that obtained when the amplitude of the local oscillation is *equal* to that of the signal, is of the order 55 to 1.

I do not pick any definite holes in either Mr. Voss's or Mr. Ryan's theories, simply because they are stated in a form in which one cannot say that this or that is definitely wrong (or, for that matter, right !), therefore, I quote the theory I am working on.

In his letter, Mr. Voss states : " If the local oscillations are . . . stronger . . . than the incoming signals, the beat amplitude suffers . . . " *Why ?*

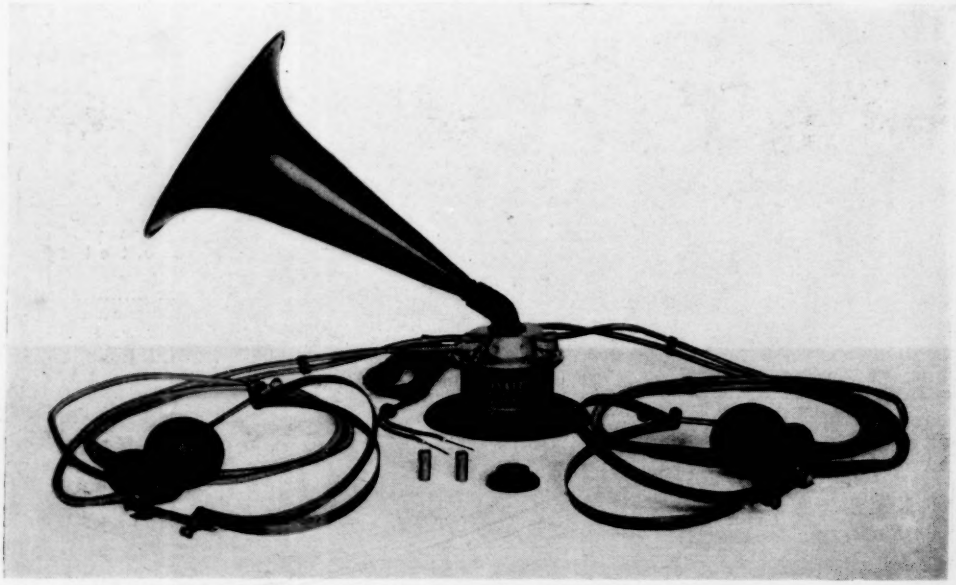
It would appear from the foregoing that this is anything but true. If Mr. Voss's statement is true, how does he explain (1) the results of Armstrong's experiments, and (2) where does he find the error in the reasoning I have used above ?—Yours faithfully,

DESMOND DE BURGH,
F/L., R.A.F.

Business Brevities.

THE BARNES' MULTIPHONE.

The Barnes' Multiphone seems to be the really first application of a principle which was suggested, and, in fact, tried out, some years ago. Briefly described, it consists in causing a common diaphragm to excite an air chamber fitted with a number of outlets which communicate with a number of earpieces or other devices. The Multiphone is shown in the accompanying illustration, and the method of construction should be readily apparent. The movement comprises a substantial magnetic circuit with a fairly thick adjustable diaphragm. The air chamber somewhat resembles a capstan head, and is provided with a number of tapering slots arranged radially into which can be plugged the headphone " leads." These, of course, are merely flexible tubes, terminating in " earpieces " consisting essentially of pressed metal discs fixed to a light head-band. The top of the air chamber contains a larger tapering hole, into which a loud speaker horn can be fixed. When the horn is not required the hole is closed with an ebonite " stopper," and similarly the headphone leads may be replaced by small metal plugs. On test



The Barnes Multiphone provides for a loud speaker horn and four pairs of headphones.

the headphones gave very good quality reproduction and fairly good strength considering that four pairs were in operation simultaneously. The tone is rather on the deep side, but is certainly not too deep. We were not quite so pleased with the volume from the loud speaker, but on normal load the quality was quite good. After being accustomed to ordinary telephone leads, the comparatively heavy flexible tubing seemed to make its presence well known ; perhaps it might be possible to substitute it by rubber tubing. The Barnes' Multiphones should appeal to those interested in headphone reception of broadcasting, since four pairs of telephones and a loud speaker are available at practically the same cost as that of a small loud speaker.

Showing the construction of the switch on the Fuller Tone Controller.

* * *

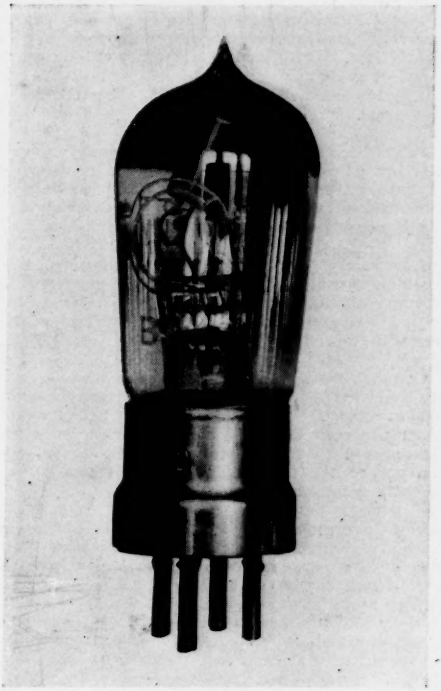
THE FULLER TONE CONTROLLER.

We have received for test from Messrs. Fullers United Electric Works, Ltd., one of their standard tone controllers, which is shown in the accompanying illustration. As its name implies, it is intended to control the tone of music or speech in the telephones or loud speaker. It will be seen that there are two input and two output terminals, which are connected respectively to the output of the set and the telephones or loud speaker. The device is fitted with a special six-leaf radial switch, which connects in parallel a number of studs communicating with a series of condensers connected in parallel with the input and output terminals. In operation it is found to be very effective in altering the tone of the received signals, and in particular one can usually find a best setting for speech and a best setting for music. To those of refined musical tastes it should make a special appeal.

* * *

ANOTHER ORA VALVE.

The O.R.A. "A" and O.R.A. "B" valves are too well known to need any introduction to our readers. Another has now been added to the group in the form of the D.F. O.R.A., which is somewhat similar to the original types, but is made with a thoriated high-resistance filament similar to that used in the UV199. The shape and position of the electrodes can be gathered from the accompanying photograph. The filament current is 60 milliamps. at 2 to 3 volts, with a fairly heavy emission, as much as about 12 milliamps. being obtainable. With 100 volts on the anode a grid-bias of about 5 volts is required when used as an amplifier. The valve should be especially useful for compact portable sets where battery power is limited. We would remind our readers that a valve with so thin a filament requires very careful handling.



The new D.F. Mullard ORA.

Experimental Notes and News.

The next Wireless Exhibition under the auspices of the National Association of Radio Manufacturers will be held at the Royal Albert Hall, London, during the last week in September next and the first week of October. It is intended to demonstrate present-day wireless achievement under the best possible circumstances.

* * *

The time signals broadcast from London are now sent direct from Greenwich Observatory, instead of from Paris.

* * *

The morning broadcast concert from 2LO is to be resumed at an early date. This is a concession to night-workers who are unable to listen to the usual programmes.

* * *

Sir Henry Thornton, the President of the Canadian National Railways, is arranging to provide wireless receiving sets for 100,000 workers on that company's line. Broadcasting stations will be established at various points of the 22,000 miles of railway, and sets will be supplied to the workers at cost price.

* * *

It has been stated that over 12,000 miles of aerial wire have been erected in Britain during the past twelve months. Over £100,000 has been paid by the British Broadcasting Company in fees, copyright royalties, and salaries for the wireless concerts.

* * *

Australia's first broadcasting station has been established at Willoughby, eight miles north of Sydney. A cage aerial 575 feet long, is used, supported between two towers 200 feet high. The wave-length is 1,100 metres, and the call is 2FC.

* * *

Complaints of oscillations in the London area are recorded at B.B.C. headquarters by inserting pins in a map. The pins are removed once a month when the complaints have been investigated and cleared up. Forest Gate, Stratford, Acton, and Ealing are the districts where most trouble has recently been experienced.

* * *

The Government of India are inviting applications from private enterprise for licences to establish and operate the necessary radio service to provide the Indian link in the Imperial Wireless Scheme. The service required entails the installation of a station capable of conducting high-speed duplex radio communications in two directions simultaneously, together with simultaneous reception from at least three other directions, at a rate of charge which shall not exceed the cable rates from time to time prevailing. Direct communication with the United Kingdom or South Africa on the one hand, and Australia or Canada on the other, must be guaranteed.

* * *

It is stated that owing to the depression in the shipping industry, more than 2,000 competent marine wireless operators are unemployed. On the other hand, there appears to be a shortage of operators in the Royal Air Force. In the latter service, all wireless operators will be given the rank of Leading Aircraftsman or Aircraftsman (First Class) as soon as the attestation test has been passed, according to the skill shown. This carries with it pay at the rate of 5s. 2d. or 4s. 6d. a day. All operators are fed and clothed. By attaining the rank of first-class sergeant-major it is possible to obtain pay at the rate of 15s. a day.

* * *

The Liverpool Relay Station is to be constructed immediately after the completion of the Edinburgh Station. B.B.C. engineers have already visited Liverpool to examine possible sites.

* * *

The British Broadcasting Company are considering the establishment of a new high-powered broadcasting station just outside the London area. The proposal is to put up a 25-kilowatt plant, working on a wave-length of 1,600 metres. It is thought that the new station, if definitely proceeded with, will facilitate crystal reception up to 100 miles, single-valve reception up to 200 miles, and two-valve reception anywhere in the United Kingdom. Permission has already been given by the Postmaster-General to erect such a station for experimental purposes. A permanent license would be subject to the new transmission not interfering with Government services.

* * *

Dundee is anxious to have a relay broadcasting station. A sub-committee of the Town Council has been appointed to interview the G.P.O. officials and others in connection with the scheme.

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A demonstration of a new device for preserving the secrecy of wireless messages has been recently given in Birmingham. The device provides for the reception on one aerial and one receiver messages of two, three, or any number of different wave-lengths. By transmitting messages of which the alternate words were on different wave-lengths, in accordance with an agreed code, secrecy would be preserved.

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The Housing Committee of the London County Council have decided to dispense with the deposit which was required from tenants desiring to instal wireless apparatus. A deposit of £1 is, however, still required from tenants of block dwellings.

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On a recent trip of the *Aquitania* the wireless aerials were arranged to work one on 600 metres and the other on 1,200 metres. By working a double shift, messages were handled with much greater ease than usual, and during the voyage 100,000 words were transmitted as against 60,000 on a normal voyage.

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Complaints are being made that the Radio Corporation of America have established a monopoly in wireless apparatus in restraint of trade. The Corporation comprises a number of the leading wireless manufacturing companies in the United States, and the Federal Trade Commission has entered a charge against them.